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BENEFIT-COST MODEL FOR THE EVALUATION OF SIMULATOR-BASED MULTISHIP TRAINING ALTERNATIVES

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This paper presents a general model that allows for the benefit-cost evaluation of multiship training simulation systems that provides a decision-assisting tool to Air Force managers. The usefulness of the model is demonstrated by means of an application which is based on actual data. The model allows for full sensitivity analysis and variation of organizational alternatives, benefit and cost parameters. A set of LOTUS 1-2-3 spreadsheets were developed which demonstrate the model and are interlinked in such a way that the effects of changes in the model or in the data used by the model may be easily seen.

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PREFACE

The research reported in this paper was conducted at the Armstrong Laboratory, Human Resources Directorate, Aircrew Training Research Division, at Williams Air Force Base, Arizona, under Work Unit 1123-05-01, In-House Research and Development Support.

The purpose of this research was to develop a general model that would allow for the benefit-cost evaluation of multiship training simulation systems. The model developed is a decision-making tool for Air Force managers to compare between and among different simulation systems intended to supplement and enhance aircrew training.

The model developed was implemented through a series of LOTUS 1-2-3 spreadsheets to facilitate analysis and "what-if" comparisons. The spreadsheets' design and use are described in this paper and illustrated in the appendixes.

BENEFIT-COST MODEL FOR THE EVALUATION OF SIMULATOR-BASED MULTISHIP TRAINING ALTERNATIVES

INTRODUCTION

The purpose of this project is to develop a method of applying the technique of benefit-cost analysis to the evaluation of simulation systems which are intended to provide training to pilots in the United States Air Force (USAF). While benefit-cost analysis is a widely documented and well understood technique, the mechanisms for establishing and measuring benefits are not universally defined and must be developed for each specific application. The evaluation of using simulation as a training technique is one such application area.

Simulation as a means of helping to train pilots to fly war planes has been used since World War II (or before) and is widely used. However, many of the simulation systems that have been widely adopted provide a relatively narrow training spectrum such as emergency procedures or instrument training. Nonflying, computer-based simulation systems capable of assisting in much wider spectra of pilot needs exist but are generally confined to single systems being studied in research and development environments.

With the rapid technological improvements made in microcomputers and vision systems, it is possible to construct relatively inexpensive, high performance simulation systems that could be used to meet many of the training enhancement needs of the Air Force. The difficulty would be to select the system, or systems, which would provide the greatest training benefit at a cost within budgetary limitations. Providing a benefit model that would be applicable to any simulation system, either currently available or proposed, would help to alleviate this difficulty. The focus of this evaluation would be on an Air Force-wide implementation of simulation systems rather than the design or use of any single system.

In addition, most simulation systems are not constructed to enhance multiperson (or multiship) interaction in the simulated environment. Since the USAF norm is that war planes fly and fight in pairs, or in multiples of pairs, it would be useful to have simulation systems that emphasized this important characteristic. Developing a benefits model which provides the basis for economically evaluating and comparing such systems would help assure that useful as well as economic systems would be implemented.

This report attempts to help meet the above needs by presenting a benefit-cost measurement model that can be applied to any simulation system or environment proposed for multiship training simulation. It accomplishes this by first creating a set of possible simulation alternatives that could provide simulation-based multiship training. It then presents attributes of simulation environments which form the basis for evaluating the benefits of the simulation alternatives. These attributes are combined with evaluation elements to form a benefits model which can yield the estimated dollar values that are used in establishing benefit-cost ratios. The cost model used is

based on existing accounting models, Air Force regulations, and cost estimates drawn from literature and expert opinion. The overall benefit-cost model is applied to the alternatives to illustrate its usability.

Benefit-Cost Analysis

There is a general consensus in the economic literature that a benefit-cost analysis is appropriate for any government program that involves an impact on a segment of the population [Maciariello, 1975; Pearce, 1983; Steiner, 1980]. Enhancing the training of pilots for the USAF meets this criterion. Therefore, alternative methods of providing such training should be amenable to this analysis.

There is also a general agreement [Maciariello, 1975; Pearce, 1983; Oxenfeldt, 1979] that a benefit-cost analysis includes:

1. A specification of the goal(s) or objective(s) which the programs are intended to achieve.

2. An enumeration and definition of the alternatives which are proposed as mechanisms for reaching these goal(s).

3. A definition of the means of evaluating the benefits derivable from each alternative. This includes the definition of the means of converting benefits into quantitative (dollar measurable) terms.

4. A definition of the means of evaluating the costs required to implement each alternative.

5. A completed analysis showing the computed incremental benefit/cost (B/C) ratios for all alternatives being evaluated. Alternatively, incremental net benefits may be used as a basis for evaluating alternatives.)

The specific goal for the alternatives to be evaluated in this review is "to enhance the training of combat pilots through the use of multiship simulation systems." Therefore, the benefit-cost analysis should provide a means of comparing any alternative which has the capability of achieving this goal. A representative set of alternatives which meet the goal and the criteria by which they were generated will be presented in the next section.

However, the development of the means of evaluating the benefits of these alternatives is regarded as the most important aspect of this review. There are no agreed-on methods for constructing metrics for evaluating benefits [Maciariello, 1975; Smith, 1986; McDonald et al., 1989] but it is understood that whatever method is developed, it must yield a quantitative output in monetary terms. An important element to note here is that the method used to measure the benefit does not necessarily imply any replacement of existing capability. That is, measuring the benefit of an added capability in terms appropriate to an existing capability does not mean that the existing capability can be replaced by the addition. In the appropriate language, this is referred to as maintaining a "static framework of analysis" [Maciariello, 1975, p. 4].

Organizational Alternatives

The alternatives generated for this project are based on criteria concerning multiship simulation developed through an extensive literature search [Amdor et al., 1988; Institute for Simulation & Training, 1990; McDonald et al., 1989; Lethert, 1985; Graham et al., 1981] and discussions with experts in the field of simulation training [Houck, et al., 1990; Genet, 1988; Bell, et al., 1990]. It was felt that two sets of criteria were appropriate. One set to describe the conditions which a simulation system must meet to satisfy the goal specified for the benefit-cost analysis, and a second set to describe the conditions of the "simulation environment" experienced by the pilot engaged in the multiship simulation experience.

The first set of criteria defines the conditions to be met for systems to be considered organizational alternatives which would satisfy the needs of, at least, a definable, operational segment of the Air Force. These criteria are shown in Table 1.

Table 1. Criteria for Organizational Alternatives

1.	Each alternative must be constructed in such a manner that it is mutually exclusive which respect to each other alternative [Pearce, 1983].
2.	Each alternative must be capable of providing multi-ship training/practice/maintenance of skills to all pilots within a definable segment of the Air Force.
3.	Each alternative may include one, or more, simulation environments which may not be exclusive between alternatives.
4.	The alternatives will be established with respect to a specific aircraft type and configuration.
5.	The alternatives are intended to serve operational units (wings or squadrons), not units devoted primarily to training new or cross-training pilots.

The simulation environments are defined to be the man-machine interfaces which will be experienced by the pilots who are to receive the training via simulation. Table 2 shows the basic set of criteria for a simulation environment which will provide multiship training.

Table 2. Criteria for Multiship Simulation Environments

1.	The simulation environment must accommodate at least two pilots (lead and wingman) simultaneously [Bell, et al., 1990; McDonald et al., 1989].
2.	Each pilot must be able to "see" his lead/wingman in the appropriate positions at all times (if this is possible in the actual aircraft). This refers to visual as well as other means of locating the supporting aircraft.
3.	The physical environment (cockpit) of each pilot should be correct in terms of the aircraft being simulated [Olsen, 1982].
4.	Communication linkages must be provided which reflect current practice, including the capability of ground control interaction.
5.	The simulation environment must be kept physically updated to reflect the aircraft the pilot is actually flying.

ORGANIZATIONAL ALTERNATIVES - EXAMPLE APPLICATION

Conditions To Be Met by Alternatives

Based on the criteria for organizational alternatives and the expertise and development efforts in simulation training being accomplished at the Armstrong Laboratory Human Resources Directorate, Aircrew Training Research Division, at Williams Air Force Base, Arizona, the following conditions were established to assist in configuring these organizational alternatives. These conditions are intended to make the alternatives as realistic as possible for a peacetime Air Force. The conditions are also established to narrow and focus the number of different choices that would otherwise have to be evaluated in shaping the alternatives.

1. The emphasis is on F-15s, exclusive of F-15Es. The F-15 is an air superiority jet fighter which was originally configured for air-to-air combat. The F-15E is a newer configuration with added air-to-ground capability currently being brought into use in the Air Force [Department of the Air Force, 1988b; 1989]. Focusing on the F-15 (C and D configuration) reduces the number of operational squadrons to be served by the organizational alternatives and the number of training purposes which must be served.

2. There are approximately 18 squadrons (6 wings) of F-15s to be served by the organizational alternatives to be evaluated. Assuming there are

approximately 450 F-15s in active operational service and that the pilot force ratio is 1.25 per aircraft and that there are approximately 22 to 26 aircraft per squadron, there would be approximately 32 pilots per squadron (plus flying rated officers not counted in the pilot force ratio). This yields an estimate of approximately 600 to 650 pilots to be served by the simulation alternative [Department of the Air Force, 1982; International Institute for Strategic Studies, 1989; AIR FORCE Magazine, 1990].

3. There are approximately 50 working/flying hours in the current work week for pilots. Of these, no more than 5 to 6 hours would be available for additional simulation training (including briefing, simulation runs, and debriefing).

4. All simulation training/practice would be performed between 0700 and 1900 during the normal work week. Allowing for a 1/2 hour briefing before the simulation run and a 1 hour debriefing, the simulator could be run between 0730 and 1800. This allows for approximately 10.5 hours of simulation sorties per cockpit per day per simulation environment.

5. If there are an average of 35 pilots per squadron and each pilot receives 2 simulation sorties per week, each simulation organizational alternative should allow for 70 simulation sorties per week per squadron.

6. All sorties and simulation runs are performed by, at least, 2 plane (pilot) elements.

7. Each organizational alternative should provide for the use of ground control and 2 (or more) opponent aircraft (human or computer control).

8. All components used in the alternatives must be currently commercially available or be developed to the extent that commercial specifications can be stated.

9. Each organizational alternative should include the capacity to build and disseminate simulation databases to locations of use.

Alternative Components

Using the general criteria for organizational alternatives and the conditions established for these alternatives, the following components were selected to form an example set of organizational alternatives:

1. Combat Engagement Trainer (CET). Includes a cockpit which correctly emulates an F-15 and its information displays, all necessary computer cables, blackout canopy, etc. (does not include the computers necessary to operate the CET).

2. Display for Advanced Research and Technology (DART) Dome. Includes a cockpit which correctly emulates an F-15 and its information displays, a dome composed of hexagonal projection panels for computer-generated displays, all necessary computer cables, all necessary projection equipment, etc. (does not include the computers).

3. Visual Display Helmet with Head Tracking Equipment. Includes all necessary computer cables, etc. (does not include the computers).

4. Fiber Optic Helmet-Mounted Display (FOHMD) with Head Tracking Equipment. Includes all necessary computer cables, etc. (does not include the computers).

5. Control/Communication/Linkage Computer

a. Level I - Links two CETs to fly as an element (could be used for 1 v 1 practice). Used to receive the download of a display data base. Allows for computer-generated opponents.

b. Level II - Possesses all characteristics of Level I. Can handle input/output functions for up to 4 v 4 engagements.

6. Host Computer. Linked to simulation environment for display and interaction.

a. Host I - Linked to CET in Level I configuration.

b. Host II - Linked to CET in all other configurations (capacity is adequate for 4 v 4 engagements).

c. Host III - Linked to DART dome and visual display helmet.

d. Host IV - Linked to DART dome and visual display helmet.

7. Image Generated (IG) Computer. Computer necessary for generating appropriate images for the DART dome.

a. IG I - Linked to DART with visual display helmet.

b. IG II - Linked to DART with FOHMD.

8. Ground Control Intercept (GCI) Computer. Computer which allows the simulation center manager (or other person) to act as a ground control officer.

9. Briefing/Debriefing Computer and Displays. Basically, a small computer for the named purpose and/or pilot reviews of archived simulation flights.

Specification of Alternatives

Based on the criteria and conditions for organizational alternatives, the following four alternatives were established. These alternatives form a representative set rather than an exhaustive set of ways multiship simulation training could be provided to operational pilots. Block diagrams representing these alternatives may be seen in Appendix A.

Alternative I. Pair of CETs with visual display helmets in each squadron, no cross-linking between squadrons. Direct (download) link with Data Base Development Center. Ground control provided by simulation personnel (permits element simulation with computer opponent).

Alternative II. Pair of CETs with visual display helmets in each squadron, full cross-linking among squadrons within the wing, no other cross-linking possible. Direct (download) link with Data Base Development Center. Ground control provided by simulation personnel (permits up to 4 v 2 simulation with human opponent).

Alternative III. Pair of CETs with visual display helmets in each squadron and a pair of DART domes with visual display helmets at a wing location, full cross-linking among all elements within the wing, no other cross-linking possible. Direct (download) link with Data Base Development Center. Ground control provided by simulation personnel (permits up to 4 v 2 simulation with human opponents).

Alternative IV. Pair of CETs with visual display helmets in each squadron and four regional centers, each center with four DART domes with FOHMD (pilots would cycle through regional centers), full cross-linking among any set of four squadrons (for each regional center). Direct (download) link with Data Base Development Center (permits up to 4 v 4 simulation with human opponents).

BENEFITS MODEL - GENERAL DEVELOPMENT

The development of the general method for benefits measurement is based on the desire to create a general model that (a) would be able to evaluate any proposed alternative for multiship simulation training, (b) would be acceptable and usable by both those who develop such simulation systems as well as those trained; (c) would be easily understood and manipulated for evaluation and sensitivity analysis, (d) would maintain internal consistency so that a set of different organizational alternatives could be usefully compared, and (e) could yield dollar figures for internal comparison without the demand that these same "dollars" could ever be found in a balance sheet.

To these ends, the following conditions were imposed:

1. The well-documented concept of transfer effectiveness ratios (Orlansky & Chatelier, 1983; Orlansky & String, 1982) would not be used. Transfer effectiveness ratios specifically assume that simulation would be used instead of the aircraft. It is the explicit assumption of this research that no replacement of aircraft flying hours would take place. All benefits accruing due to the use of simulation would be derived as <u>additions</u> to the training/preparedness of the pilots.

2. As much comparison to the way the actual aircraft is used for operational training was sought.

3. The concept of "shadow prices" was implicitly used. The "shadow price" could be the marginal cost of actually using the aircraft if

compared to training currently taking place but could be adjusted (upward or downward) to account for the costs of training for activities proscribed for the aircraft in a peacetime environment (e.g., electronic warfare countermeasures, air-to-air missile use).

4. The assumption is that, with rapid changes in technology and weaponry, no pilot is ever fully trained in all aspects of multiship combat. Therefore, the learning curve for each pilot is in its linear portion prior to becoming asymptotic.

Performance Areas

For purposes of this project, a performance area is defined as an operational activity for which a sortie would be scheduled so that a pilot could acquire, improve, or maintain the skills necessary to carry out that specific activity. It is assumed that the performance area is sufficiently "large" in numbers of behavioral skills that a sortie would be practicable for each specific performance area. It is recognized that, in reality, many sorties are used to practice more than one performance area, but for purposes of comparison only, "pure" sorties (exactly one performance area) are being considered.

The Performance Areas are identified as PA(i), where i refers to a specific performance area and m is the maximum number of performance areas to be investigated for the set of organizational alternatives (i = 1, ..., m).

Simulation Environment

Simulation environment is the environment (inside the simulator) of the pilot who is practicing the Performance Area. Each simulation environment would not, necessarily, be unique to a specific organizational alternative. The evaluation of an alternative will combine the appropriate simulation environments. The SIMulation environment is identified as SIM(j); where j refers to the specific simulation environment and n is the total number of environments for the set of organizational alternatives (j = 1, ..., n).

Degree of Emulation

Emulation is a term being used to represent the degree to which a specific simulation environment represents the actual environment experienced in the aircraft for the specific performance area. This term can only be numerically defined by a pilot experienced in the aircraft in question and experienced in the specific simulation environment. It is a subjective measure that includes all aspects of flying. The value of the emulation would be measured by expert opinion, properly controlled, and would range from a value of 0.00 for a totally useless simulation environment to 1.00 for a simulation environment that perfectly matched the aircraft. (Strictly speaking, this scale should allow for negative values for a simulation which negatively influences training/learning.)

The Emulation capability of the SIMulation environment is identified as ESIM(i,j).

The relationship among PA(i), SIM(j) and ESIM(i,j) may be shown graphically:

		Simulation Environments						
		1	2	. . . .	j	. . . .	m	
	1							
	.							
Performance Areas	i				ESIM(i,j)			
	.							
	n							

Aircraft Training/Practice Sortie. A sortie where one, and only one, performance area is practiced. The aircraft is flown and "reset" as many times as possible in the sortie to repeat the same activity.

1. Aircraft Sortie Duration: The average time for such a sortie for each performance area.

The Aircraft sortie Time is identified as AT(i).

2. Performance Area Iterations: The number of times the specific performance could be practiced per sortie.

The Aircraft Repetitions are identified as AR(i).

Simulation Training/Practice Sortie. A simulation run devoted to the practice of one specific performance area.

1. Simulation Sortie Duration: The average time for such a sortie for each performance area. This time period is intended to be held equal to the corresponding aircraft sortie duration to facilitate later computations.

The Simulation sortie Times are identified as ST(i).

2. Simulation Performance Area Iterations: The number of times the specific performance could be practiced per simulation sortie.

The Simulation Repetitions are identified as SR(i).

Degree of Simulation Compression. Ratio of the number of times a given Performance Area can be practiced in a simulator versus an aircraft. This provides a measure of the increased (normally) training/practice capacity of the simulation environment.

The Degree of Simulation Compression is identified as DSC(i,j) and is computed by SR(i,j)/AR(i).

Simulation Benefit Factor. Simulation Benefit Factor is a correction factor computed from the simulation compression factor and the degree of emulation. This factor is used directly in computing the overall benefits imputed to each organizational alternative.

The Simulation BENefit factor is identified as SBEN(i,j) and is computed by ESIM(i,j)*DSC(i,j).

Directly Measured Benefit Elements. These factors are based on the shadow costs for the use of aircraft and weaponry approximated by the marginal costs of the equipment. These factors are intended to directly reflect the training/practice benefit accruing due to the use of simulation.

1. Marginal (incremental) Aircraft Cost. Cost of flying the aircraft on a per sortie basis (or per hour), corrected for Performance Area if appropriate.

The Marginal Aircraft Cost is identified as MAC$(i).

2. Weaponry Cost. Cost of using ammunition, weaponry or other consumables expended per aircraft sortie for each Performance Area. This cost would include a factor for all damage (peacetime) due to the use of the weaponry.

The WEAPonry cost is identified as WEAP(i).

Indirectly Measured Benefit Elements. These factors are based on potential losses of pilots and aircraft used in flying sorties. They are indirect in the sense that they are based on sortie time rather than a measure of training benefit. They are a measure of risk rather than training.

1. Aircraft Loss Cost. Cost of loss of the aircraft as a function of its use in flying sorties of the specific Performance Area. This is a probability-based measure computed by (Cost of an aircraft)*(Probability of loss per sortie).

The AIRcraft loss Cost is identified as AIRC$(i).

2. Pilot Death Cost. Cost of losing a pilot due to a training accident as a function of his exposure to risk in specific Performance Areas. This is a probability-based measure computed by (cost of the pilot)*(Probability of loss per sortie).

The PILot death Cost is identified as PILC$(i).

Number of Simulation Sorties. The total number of simulation sorties that can be performed in a specified simulation environment for each Performance Area for each organizational alternative in a year. This number is the basis for the computation of the total estimated benefits accruing.

The NUMber of sorties is identified as NUM(i,j).

Total Benefits Model. The total estimated benefits for each organizational alternative per year is computed by the following equation:

$$\text{Benefits} = \sum_i \sum_j \{NUM(i,j)*SBEN(i,j)*MAC(i)\} + \sum_i \sum_j \{NUM(i,j)*SBEN(i,j)*WEAP\$(i)\} + \sum_i \sum_j \{NUM(i,j)*(AIRC\$(i) + PILC\$(i))\}$$

These values, for each alternative in a set of alternatives, are the benefits values for the final benefit cost evaluation. The total benefits model including all subordinate tables and values has been implemented in the form of a LOTUS 1-2-3 spreadsheet which allows for relatively easy arithmetic manipulation and sensitivity analysis.

BENEFITS MODEL - EXAMPLE APPLICATION

The intent of this application is to demonstrate the utilization of the benefits model to as realistic a situation as possible. In order to allow for this, an "unrealistic" use of simulation is specified to directly duplicate the training/practice of combat pilots as it is currently being performed in operational squadrons. To this end, intensive interviews with pilots, and review of Air Force and other government documents are used to make estimates of the various components of the benefits computation.

It is suggested that, based on the assumptions previously stated, the more practical, "real" use of simulation is to train in performance areas which are proscribed in peacetime. However, to model benefits in this situation would make examination and validation of results far more difficult.

Performance Areas. The performance areas selected for the model are drawn from Air Force Manual (AFM) 51-50 used for specifying squadron operations [AFM 51-50, 1989]. These areas, "tasks" in the manual, are the actual operational purposes of sorties scheduled. As such, they are well understood by pilots and allow for direct comparison to uses specified for simulation environments.

These are the same as "tasks" identified in Table A1-2, Standard Sortie Planning Factors, of AFM 51-50. A total of 20 such planning "tasks" are shown in this table but only the last seven are appropriate for F-15 air-to-air comparison. These are numbered in the order shown in the Table and listed below.

Performance Areas used for this example:

Air Superiority		Air Defense	
14.	Intercepts (Day/Night)	18.	Intercepts (Day/Night)
15.	ACBT	19.	ACBT
16.	DART	20.	DART
17.	CFT		

Simulation Environment. The simulation environments are defined by the Organizational Alternatives previously presented and shown below.

Simulation Environments used for this example:

1. CET cockpit - visual display helmet, linked to one other simulated environment, opponents computer generated.

2. CET cockpit - visual display helmet, may be linked to more than one other simulated environment, opponents may be human piloted.

3. DART dome cockpit - visual display helmet, may be linked to more than one other simulated environment, opponents may be human piloted.

4. DART dome cockpit - FOHMD helmet, may be linked to more than one other simulated environment, opponents may be human piloted.

Degree of Emulation. Values for the ESIM(i,j) factors were derived from a series of intensive interviews with fighter pilots (an average of over 18 years experience) who were also experienced with the use of simulation. None of these pilots were willing or able to provide more than very approximate values for the factors nor were they able to distinguish among the performance areas as to differential effects. Due to the degree of approximation, the lowest estimated values were used.

Table 3. Matrix of Values for Emulation Measures

ESIM(i,j)

Performance areas	Simulation Environments (j)			
	CET	CET	Domes	Regional Centers
(i)	Not Linked 1	Interlinked 2	CET in squad 3	CET in squad 4
14	0.0150	0.0300	0.0700	0.1000
15	0.0150	0.0300	0.0700	0.1000
16	0.0150	0.0300	0.0700	0.1000
17	0.0150	0.0300	0.0700	0.1000
18	0.0150	0.0300	0.0700	0.1000
19	0.0150	0.0300	0.0700	0.1000
20	0.0150	0.0300	0.0700	0.1000

Aircraft Training/Practice Sortie. The same series of interviews with experienced pilots yielded average figures for sortie duration and number of repetitions for the performance areas. The values for repetitions were the maximum values of the estimates.

Table 4. Aircraft Sortie Values

Aircraft Sortie Time AT(i)	Aircraft Repetitions AR(i)
1.40	6
1.30	3
1.30	3
1.30	3
1.40	6
1.30	3
1.30	3

Simulation Training/Practice Sortie. The pilot interviews were used to establish time estimates for the time to repeat one iteration for each performance area. This time was doubled (to allow for resetting the simulation environment) and used to establish the number of repetitions within each simulation environment. ST(i) is held equal to AT(i).

Table 5. Simulation Repetitions

SR(i,j)			
1	2	3	4
10	10	10	10
8	8	8	8
8	8	8	8
8	8	8	8
10	10	10	10
8	8	8	8
8	8	8	8

Simulation Benefit Factor. The table of simulation benefit factors was computed using the above data. Note that this table includes in the computation the values for the degree of simulation compression.

Table 6. Simulation Benefit Factors

SBEN)(i,j) = ESIM(i,j)*(SR(i,j)/AR(i))			
1	2	3	4
0.0250	0.0500	0.1167	0.1667
0.0400	0.0800	0.1867	0.2667
0.0400	0.0800	0.1867	0.2667
0.0400	0.0800	0.1867	0.2667
0.0250	0.0500	0.1167	0.1667
0.0400	0.0800	0.1867	0.2667
0.0400	0.0800	0.1867	0.2667

Benefit Elements. The values for the benefit elements were derived from the 1988 and 1989 Air Force budgets (Department of the Air Force, 1987; 1988a; 1988b) plus other documents which delineated estimates for the value of a pilot's life (U.S. General Accounting Office, 1987), costs of operating an F-15 (Institute for Simulation & Training, 1990), and costs of various weapons (Department of Defense, 1990). The very arbitrary estimate was made that, in the two-year period (1988 and 1989), two aircraft had been totally lost and four pilots killed. These estimates were combined with total hours flown in those two years to estimate the loss cost values. All cost figures were corrected using Consumer Price Index (CPI) correction values (Directorate of Engineering and Services, 1988, p. 6) to appropriate 1990 values.

Table 7. Benefit Conversion Factors

Aircraft use MAC$(i)	Weapons use WEAP$(i)	Loss of aircraft AIRC$(i)	Loss of pilot PILC$(i)
$6,300.00	$2,000.00	$266.00	$116.76
$5,850.00	$2,000.00	$247.00	$108.42
$5,850.00	$2,000.00	$247.00	$108.42
$5,850.00	$2,000.00	$247.00	$108.42
$6,300.00	$2,000.00	$266.00	$116.76
$5,850.00	$2,000.00	$247.00	$108.42
$5,850.00	$2,000.00	$247.00	$108.42

Number of Simulation Sorties. The number of simulation sorties available for each simulation environment for all F-15 squadrons and pilots was calculated based on the following assumptions about operating hours and procedures.

1. All squadron and wing simulation centers would operate 12 hours per day for a 5-day week, 50 weeks per year.

2. The regional simulation centers would operate 8 hours per day for a 5-day week, 50 weeks per year.

3. Pilots would always be available to take part in the simulation sorties (There are more pilots than aircraft in all squadrons.).

4. A 20% reduction in maximum number of sorties was used to account for scheduling errors, illness, equipment malfunction, etc.

5. All performance areas would be simulated equally, there is insufficient evidence to assume otherwise.

Table 8. NUM(i,j) per year

1	2	3	4
7200	7200	2400	2600
7200	7200	2400	2600
7200	7200	2400	2600
7200	7200	2400	2600
7200	7200	2400	2600
7200	7200	2400	2600
7200	7200	2400	2600

The values in this table would be used on a column-by-column basis depending on the organizational alternative being evaluated, combining the simulation environments available in a particular alternative. The remaining columns would be set to 0.0 to reflect their nonuse in the alternative.

Total Benefits Model. Table 9 shows the final benefits components for Organizational Alternative I, previously defined, while Table 10 shows only the total benefits estimate for the three remaining organizational alternatives.

Table 9. Overall Benefits Imputed to Organizational Alternative I (Using only CET Environments in Squadrons)

$32,598,864.00

1	2	3	4
$4,249,872.00	$0.00	$0.00	$0.00
$4,819,824.00	$0.00	$0.00	$0.00
$4,819,824.00	$0.00	$0.00	$0.00
$4,819,824.00	$0.00	$0.00	$0.00
$4,249,872.00	$0.00	$0.00	$0.00
$4,819,824.00	$0.00	$0.00	$0.00
$4,819,824.00	$0.00	$0.00	$0.00

Table 10. Overall Benefits Imputed to Organizational Alternatives

Organizational Alternative II	$46,890,864.00
Organizational Alternative III	$75,225,152.00
Organizational Alternative IV	$87,908,342.67

COST MODEL - GENERAL DEVELOPMENT

The cost model was developed in order to follow, as closely as possible, rules and procedures currently in use by the Air Force. In this case, the development of the model becomes a case of selecting, rather than defining or deriving, the key cost elements which must be used in evaluating Organizational Alternatives. The following represents the key information which must be considered in the cost model. This information was extracted from Air Force Regulation 173-15, Economic Analysis and Program Evaluation for Resource Management.

1. Life-Cycle Costs (LCC) - Total costs from acquisition to disposal of a particular alternative. Discounted values for costs.

2. Nonrecurring Costs - One-time costs, unique to a specific phase of a project.

a. Research and development costs

b. Investment costs - costs associated with the acquisition of equipment, real property, start-up costs.

(1) Costs of acquisition, rehabilitation or modification of land, buildings, machinery, equipment, and one-time computer software costs.

(2) Costs of acquisition, rehabilitation, or modifications of other capital items such as furnishings and fittings required for the project.

(3) The cost of plant rearrangement and tooling associated with the project.

(4) The costs of freight and insurance required by the project.

(5) The value of nonrecurring services received from others.

(6) The costs of leaseholds required for the project.

(7) Working capital and current assets on hand or on order.

(8) Imputed value of existing Air Force assets to be employed on the project.

3. Recurring Costs - Annual costs required to operate and maintain a program or project.

a. Personnel Costs - All direct and indirect costs related to both civilian and military personnel.

(1) Gross pay
(2) Retirement and disability, health, and life insurance
(3) Sick leave and annual leave
(4) Holiday pay and other
(5) Change of station or duty pay
(6) Retirement pay
(7) Travel, per diem, moving expenses
(8) Training

b. Supplies and Material

(1) Directly consumed
(2) Transportation costs
(3) Handling, storage and protection of material
(4) Cost of utility services

c. Maintenance and Repair Costs

Sunk costs should not be counted, but may be shown separately for information.

Depreciation should only be used to estimate terminal values. In general, a discount rate of 10 per cent should be used with a midyear convention. Certain specific instances may call for a different assumption but generally not viewed as necessary.

The following factors are specified for the establishment of the economic life estimates for capital equipment.

1. The economic life of a project or asset is the time during which benefits from it may reasonably be expected to accrue to the Air Force.

2. Economic life plus project lead-time determine the time period to be considered when conducting an economic analysis.

3. Economic life of a project or asset is set by the shortest of its physical life, technological life, or mission life.

4. If necessary, a residual value will be determined to be used as a terminal value.

5. Comparing assets with different economic lives:

a. Use terminal value for the longer lived alternative.

b. Use common denominator approach (LCM).

A complete accounting structure focused specifically on all forms of simulation systems is presented in Knapp and Orlansky, 1983. This structure was abstracted for the cost elements viewed as most pertinent for Organizational Alternatives being considered here. Cost categories are presented in Table 11. Numbers attached to the categories refer to the original structure.

Table 11. Cost Categories/Elements for Organizational Alternatives

A. RESEARCH AND DEVELOPMENT
   5. Prototype Manufacturing
   7. Program/Course/Device Test and Evaluation
B. INITIAL INVESTMENT
   1. Production
      a. Nonrecurring
         (3) Industrial facilities
         (4) Other
      b. Recurring
         (1) Acquisition costs
         (2) Annual maintenance and update
      c. Initial Spares and Repair Parts
   5. Data
      b. Technical
      c. Instruction Materials
   7. System/Project Management
  10. Initial Training
      a. Instructors (On-Site Operators)
      b. Maintenance Personnel
  12. Other
C. OPERATING AND SUPPORT
   1. Direct Costs
      a. Instructional Costs
         (1) Pay and Allowances
            (a) Instructors
            (b) Supervisors, Admin, and Support
            (c) Maintenance Personnel
         (2) Other Government Personnel Costs
         (3) Consumption
            (c) Utilities
            (d) Instructional Materials
            (e) Other
         (4) Replenishments, Spares
         (5) Modification Material
         (7) Other Purchased Services
         (8) Other
      b. Training Activity Costs
         (1) Pay and Allowances
         (2) Other Government Personnel Costs
         (3) Other
      e. Other Direct Costs
   2. Indirect Costs
      a. Base Operations
      b. Inventory and Supply Management
      c. Military Family Housing Support
      d. Command Support Costs
      e. Other Indirect Costs

COST MODEL - EXAMPLE APPLICATION

The cost model application was undertaken from the basis of the general cost structure and the design specifications for the organizational alternatives as modified for the benefits application.

The data for the cost model came from interviews with AL/HRA personnel who were very familiar with the commercial simulation device market (Thomas, 1990), Air Force cost estimating manuals (Directorate of Engineering and Services, 1988; Grant and Thornley, 1987; Woolsey, 1987), civil service and military pay rates (Air Force, 1990) and the operating configurations shown in Table 12.

It was assumed that each organizational alternative would be manned by military and civil service personnel and that all buildings and equipment would be acquired new. It was further assumed that all computer-based equipment would have a 3-year economic life and that all other capital equipment would have a 9-year economic life. The cost evaluation therefore has a life cycle of 9 years.

The organizational alternatives were disaggregated into their component parts (equipment and operational) and costs were estimated for each component. Table 13 shows the component cost estimates keyed to the general cost model.

The final cost estimates were made by module within the organizational alternatives. That is, the costs necessary for one squadron-level simulation center were estimated and then total costs were created by multiplying this estimate by the 18 squadrons to be served. Table 14 shows these modular cost estimates.

Table 12. Operating Characteristics and Configurations

Physical Facilities and Staffing. (Staffing keyed to estimated civil service grades.) (Staffing assumes simulation centers run on a 12 hour/day, 5 day/week basis; Data Base Development Center run on an 8 hour/day, 5 day/week basis.)

A. Squadron Training Centers

Physical Facilities:	Staffing:
Simulation Room (14′ x 20′)	Manager/Simulation Trainer
Briefing Room (6′ x 10′)	(1 GS 7-9)
Debriefing Room (6′ x 10′)	Technical Assistant
Office/Archive/Review Room (10′ x 12′)	(1 GS 5-7)

B. Wing Training Centers

Physical Facilities:	Staffing:
Simulation Room (30′ x 60′ x 20′)	Manager/Simulation Trainer
Briefing Room (6′ x 10′)	(1, GS 7-9)
Debriefing Room (6′ x 10′)	Technical Assistant
Office/Archive/Review Room (16′ x 20′)	(1, GS 7-9)

C. Regional Training Center

Physical Facilities:	Staffing:
Simulation Room (60′ x60′ x 20′)	Manager/Simulation Trainer
Briefing Room (8′ x 12′)	(1, GS 7-9)
Debriefing Room (8′ x 12′)	Technical Assistant
Office/Archive/Review Room (16′ x 20′)	(2, GS 5-7)
Administrative Office (12′ x 18′)	Clerical (1, GS 3-4)

D. Data Base Development Center

BASE CASE (Organizational Alternatives I and II)

Physical Facilities:	Staffing:
Data Base Work Stations (4, 5′x6′)	Manager/Technical Director
(includes computer work stations)	(1, GS 12/13)
Offices (3, 8′ x 10′)	Engineer/Developer/Analyst
Meeting Room/Archive (10′ x 20′)	(3, GS 7-11)
Master Computer Room (10′ x 15′)	Technician/Programmer
Display/Study Simulator (includes one complete	(3, GS 5)
CET simulator for data base testing/validation	Clerical
Simulation Room (8′ x 16′)	(1, GS 3-4)

EXPANDED CASE (Organizational Alternatives III and IV)

Physical Facilities:	Staffing:
Data Base Work Stations (6, 5′ x 6′)	Manage·/Technical Director
(includes computer work stations)	(1, GS 12/13)
Offices (6, 8′ x 10′)	Engineer/Developer/Analyst
Meeting Room/Archive (15′ x 30′)	(5, GS 7-11)
Master Computer Room (20′ x 30′)	Technician/Programmer
Display/Study Simulator (includes one complete	(5, GS 5)
DART simulator for data base testing/validation	Clerical
Simulation Room (15′ x 25′ x 20′)	(2, GS 3-4)

Table 13. Cost Components for Organizational Alternatives

Name of Component	Estimated Cost
A. RESEARCH AND DEVELOPMENT	
5. Prototype Manufacturing	$10,000.00
7. P/C/D Test and Evaluation	$50,000.00
B. INITIAL INVESTMENT	-
1. Production	-
a. Nonrecurring	-
(3) Industrial facilities	-
Buildings to house simulation devices	-
Low Ceiling Simulator Room Costs/Sq. Ft.	$87.40
High Ceiling Simulator Room Costs/Sq. Ft.	$129.40
Office Building Costs per Sq. Ft.	$107.00
(4) Other	$10,000.00
b. Recurring	-
Acquisition cost	-
Combat Engagement Trainer (CET)	$200,000.00
Annual Update for CET cockpit	$30,000.00
DART Dome	$500,000.00
Annual Update for dome	$50,000.00
Visual Display Helmet	$100,000.00
Fiber Optic Display Helmet (FOHMD)	$500,000.00
Control/Communication/Linkage Computer-I	$10,000.00
Control/Communication/Linkage Computer-II	$30,000.00
Host Computer - Level I	$40,000.00
Host Computer - Level II	$60,000.00
Host Computer - Level III	$100,000.00
Host Computer - Level IV	$200,000.00
Image Generating Computer Level I	$200,000.00
Image Generating Computer Level II	$300,000.00
Briefing/Debriefing Computer and Displays	$10,000.00
GCI Computer	$18,000.00
c. Initial Spares and Repair Parts	10.00%
5. Data	-
b. Technical	$20,000.00
c. Instruction Materials	$20,000.00
7. System/Project Management	$0.00
10. Initial Training	-
a. Instructors (On-Site Operators)	$50,000.00
b. Maintenance Personnel	$25,000.00
12. Other	$0.00

Table 13. (Concluded)

C. OPERATING AND SUPPORT	
1. Direct Costs	-
a. Instructional Costs	-
(1) Pay and allowances	-
(a) Instructors (Simulation Operators)	-
GS 8, STEP 5	$25,351.00
GS 6, STEP 5	$20,598.00
(b) Supervisors, Admin, and Support	-
GS 3, STEP 5	$14,714.00
GS 5, STEP 5	$18,418.00
GS 10, STEP 5	$30,834.00
GS 12, STEP 5	$40,601.00
(c) Maintenance Personnel	$10,000.00
(2) Other Government Personnel Costs	25.00%
(3) Consumption	-
(c) Utilities	$25,000.00
(d) Instructional Materials	$10,000.00
(e) Other	$0.00
(4) Replenishments, Spares	$25,000.00
(5) Modification Material	$100,000.00
(7) Other Purchased Services	$0.00
(8) Other	$0.00
b. Training Activity Costs	-
(1) Pay and Allowances	-
CAPTAINS, 10 YEARS	$47,016.00
(2) Other Government Personnel Costs	-
TDY, OFFICERS, PER TWO WEEKS	$560.00
TDY, TRAVEL	$800.00
(3) Other	25.00%
e. Other Direct Costs	-
2. Indirect Costs	-
a. Base Operations	-
b. Inventory and Supply Management	-
c. Military Family Housing Support	-
d. Command Support Costs	-
e. Other Indirect Costs	$100,000.00

Table 14. Cost Estimates

Modules of Organizational Alternatives

Expenditure Type	SQUADRON CET (Pair per squadron) Not linked to other squadrons	SQUADRON CET (Pair per squadron) Linkable to other squadrons in wing	WING DOMES (Pair per wing) Linkable to CETs in squadrons
Capital, 3 year	$489,800.00	$555,800.00	$1,203,800.00
Capital, 9 year	$530,448.00	$530,448.00	$1,386,376.00
Annual costs/module	$389,936.25	$389,936.25	$554,936.25

Expenditure Type	REGION Regional Center (Four domes linkable to any 2 pairs of simulators)	SYSTEM National Data Base Center Organizational Alternatives I & II	SYSTEM National Data Base Center Organizational Alternatives III & IV
Capital, 3 year	$5,063,800.00	$248,800.00	$1,202,800.00
Capital, 9 year	$2,684,467.20	$297,157.20	$741,495.00
Annual costs/module	$1,410,616.25	$546,338.75	$707,861.25

BENEFITS COST APPLICATION

The benefits and cost data compiled for this application are summarized in Tables 15-19.

Table 15. Benefits Values

Organizational alternative	Estimated value of benefits
Alternative I	$32,598,864.00
Alternative II	$46,890,864.00
Alternative III	$75,225,152.00
Alternative IV	$87,908,342.67

Table 16. Cost Values of Modules for Organizational Alternatives

	Component Identification		
Capital Requirement Time Period	CET module Not Linked	Cet Module Linked	Wing Sim Centers
3 Years	$489,800.00	$555,800.00	$1,203,800.00
9 Years	$530,448.00	$530,448.00	$1,386,376.00
Annual	$389,936.25	$389,936.25	$554,936.25

	Component Identification		
Capital Requirement Time Period	Region Sim Centers	Data Base Center I	Data Base Center II
3 Years	$5,063,800.00	$248,800.00	$1,202,800.00
9 Years	$2,684,467.20	$297,157.20	$741,495.00
Annual	$1,410,616.25	$546,338.75	$707,861.25

Table 17. Annual Equivalent Values for Modules using 10% Interest and the End-of-Year Convention

	Component Identification		
Capital Requirement Time Period	CET module Not Linked	Cet Module Linked	Wing Sim Centers
3 Years	$196,955.44	$223,494.96	$484,064.83
9 Years	$92,106.99	$92,106.99	$240,730.33
Annual	$389,936.25	$389,936.25	$554,936.25
Equivalent Annual Values per Module	$678,998.68	$705,538.20	$1,279,731.41

	Component Identification		
Capital Requirement Time Period	Region Sim Centers	Data Base Center I	Data Base Center II
3 Years	$2,036,224.87	$100,045.96	$483,662.72
9 Years	$466,130.88	$51,598.38	$128,753.19
Annual	$1,410,616.25	$546,338.75	$707,861.25
Equivalent Annual Values per Module	$3,912,972.01	$697,983.09	$1,320,277.16

Table 18. Benefits and Costs

Annual Equivalents Values for Organizational Alternatives Assuming 18 Squadrons, 6 Wings, 4 Regional Centers and 1 Data Base Center

	Annual Costs	Annual Benefits
Alternative I 18 squadron centers	$12,919,959.29	$32,598,864.00
Alternative II 18 squadron centers, linked	$13,397,670.72	$46,890,864.00
Alternative III 18 squadron centers, linked plus wing centers	$21,698,353.27	$75,225,152.00
Alternative IV 18 squadron centers, linked plus regional centers	$29,671,852.83	$87,908,342.67

Table 19. Benefit Cost Ratios for Organizational Alternatives

Alternative	Incremental costs	Incremental benefits	Incremental benefit cost ratio
I	$12,919,959.29	$32,598,864.00	2.5231
II	$477,711.43	$14,292,000.00	29.9176
III	$8,300,682.54	$28,334,288.00	3.4135
IV	$7,973,499.56	$12,683,190.67	1.5907

As may be seen from the benefit cost ratios for the organizational alternatives, all alternatives would be attractive with the highest level of investment offering the greatest net benefit return.

A spreadsheet was developed to provide the benefit cost analysis which is linked to the spreadsheets for benefits and cost. With this spreadsheet approach, a great many sensitivity analyses may be easily performed, varying any of the parameters built into the models.

BENEFITS COST - SECOND APPLICATION

A second demonstration of the use of the benefits cost model is predicated on using performance areas which cannot be trained or practiced under peacetime conditions. The behavioral requirements within these performance

areas are extremely similar to the requirements within performance areas which are currently used, therefore, a relatively simple modification of the benefits model will demonstrate the application.

The two sets of activities are those required for the use of electronic warfare mechanisms and those for the use and dispersal of chaff during air-to-air combat. Both of these activities can be seen as taking place during the performance areas of Air Superiority and Air Defense Intercepts. Both of these performance areas would require minimal additional time on the part of a pilot during a sortie designed for their practice/maintenance. Therefore, the basic values for the benefits computation (AR, AT, SR, etc.) would remain the same; however, for the numerical example, the following assumptions are made.

1. A total of six performance areas were hypothesized corresponding to the use of Electronic Warfare Mechanisms and Chaff dispensing. No changes in the ESIM values were assumed. Tables 20 and 21 show this structure.

Table 20. Performance Areas for Second Example

(F-15 air-to-air only) Names of Performance Areas	Performance areas (i)
Air Superiority - Intercepts (Day/Night) - EW	14A
Air Superiority - Intercepts (Day/Night) - CHAFF	14B
Air Superiority - Intercepts (Day/Night) - BOTH	14C
Air Defense - Intercepts (Day/Night) - EW	18A
Air Defense - Intercepts (Day/Night) - CHAFF	18B
Air Defense - Intercepts (Day/Night) - BOTH	18C

Table 21. Matrix of Values for Emulation Measures

	Second Example ESIM(i,j) Simulation Environments (j)			
Performance Areas	CET	CET	Domes	Regional Centers
(i)	Not Linked 1	Interlinked 2	CET in squad 3	CET in squad 4
14A	0.0150	0.0300	0.0700	0.1000
14B	0.0150	0.0300	0.0700	0.1000
14C	0.0150	0.0300	0.0700	0.1000
18A	0.0150	0.0300	0.0700	0.1000
18B	0.0150	0.0300	0.0700	0.1000
18C	0.0150	0.0300	0.0700	0.1000

2. Weapons use cost (WEAP$) is assumed to increase greatly in cost but only very approximate estimates could be made. These estimated costs are shown in Table 22.

Table 22. Benefit Conversion Factors

Second Example

Aircraft Use MAC$(i)	Weapons Use WEAP$(i)	Loss of Aircraft AIRC$(i)	Loss of Pilot PILC$(i)
$6,300.00	$100,000.00	$266.00	$116.76
$6,300.00	$20,000.00	$266.00	$116.76
$6,300.00	$115,000.00	$266.00	$116.76
$6,300.00	$100,000.00	$266.00	$116.76
$6,300.00	$20,000.00	$266.00	$116.76
$6,300.00	$115,000.00	$266.00	$116.76

3. Since these two activities cannot be practiced, it is assumed all simulation sorties would be devoted to their practice, dispersed equally across all performance areas.

Table 23. NUM(i,j) Per Year

Second Example

1	2	3	4
8400	8400	2800	3000
8400	8400	2800	3000
8400	8400	2800	3000
8400	8400	2800	3000
8400	8400	2800	3000
8400	8400	2800	3000

Results of this analysis are shown on Tables 24 and 25.

Table 24. Benefits and Costs

Second Example

Annual Equivalent Values for Organizational Alternatives Assuming 18 Squadrons, 6 Wings, 4 Regional Centers and 1 Data Base Center

Alternative		Annual Costs	Annual Benefits
I	18 Squadron Centers	$12,919,959.29	$125,929,104.00
II	18 Squadron Centers, Linked	$13,397,670.72	$232,567,104.00
III	18 Squadron Centers, Linked plus Wing Centers	$21,698,353.27	$404,878,805.33
IV	18 Squadron Centers, Linked plus Regional Centers	$29,671,852.83	$493,356,784.00

Table 25. Benefit Cost Ratios for Organizational Alternatives

Second Example

Alternative	Incremental costs	Incremental benefits	Incremental benefit cost ratio
I	$12,919,959.29	$125,929,104.00	9.7469
II	$477,711.43	$106,638,000.00	223.2268
III	$8,300,682.54	$172,311,701.33	20.7587
IV	$7,973,499.56	$88,477,978.67	11.0965

While it is felt that the general benefits cost model presented is valid and useful, the extremely large values shown in this example suggest the need for further refinement of the numerical estimates of the parameters.

CONCLUSIONS

This project has succeeded in developing a general approach to benefit cost evaluation of multiship simulation systems to be used for training combat pilots. The usability of the general model is demonstrated by an extensive application based, insofar as possible, on actual data. The general model is implemented into a series of three LOTUS 1-2-3 spreadsheets allowing for

sensitivity analysis and further refinement of the variable values used in its application. The application of these spreadsheets to the examples presented in this paper is presented in Appendixes B through F.

RECOMMENDATIONS FOR FURTHER RESEARCH

It is not claimed that the results of this effort represent a complete and polished decision-assisting tool. Clearly, additional work is needed in several areas to increase its validity and usefulness.

The most immediate needs to be addressed are in the methodology for acquiring estimates of ESIM factors and a validation method for these factors. Several other factors (AR, SR, MAC$, etc.) also need to be investigated for validity. The model that is presented needs to be subjected to rigorous use through sensitivity analysis. This analysis will reveal other needs for refinement and validation.

REFERENCES

Amdor, S.L., Isley, F.W., & Pierce, B.J. (1988, July). Computer-based instruction/simulator program for fighter lead-in training: Feasibility research (AFHRL-TP-87-64, AD A197 888). Williams Air Force Base, AZ: Air Force Human Resources Laboratory, Operations Training Division,

Bentkover, J. D., Covello, V.T., & Mumpower, J. (Eds). (1986). Benefits assessment: The state of the art. Dordrecht, Holland: D. Reidel Publishing Co.

Department of the Air Force. (1988a, February). Justification of amended fiscal years 1988/1989: Operation and maintenance (AD A198 257). Air Force, Volume 1", Biennial Budget Estimates, Submitted to Congress, Washington DC.

Department of the Air Force. (1988b, February). Justification of amended fiscal years 1988/1989: Aircraft procurement (AD A198 259). Air Force, Volume 1", Biennial Budget Estimates, Submitted to Congress, Washington DC.

Department of the Air Force. (1989, January). Justification of estimate for fiscal years 1990/1991: Aircraft procurement (AD A208 997). Air Force, Volume 1", Biennial Budget Estimates, Submitted to Congress, Washington DC.

Department of the Air Force. (1987, January). Justification of estimates for fiscal years 1988/1989: Operation and Maintenance (AD A180 522). Air Force, Volume 1", Biennial Budget Estimates, Submitted to Congress, Washington D.C.

Department of Defense. (1990, January). Program acquisition costs by weapon system (AD A217 429). Department of Defense Budget for Fiscal Year 1991. Washington, DC.

Department of the Air Force, (1988, March). AF Regulation 173-15, Economic Analysis and Program Evaluation for Resource Management. Headquarters US Air Force, Washington, DC.

Department of Defense. (1989, January). Program acquisition costs by weapon system (AD A204 415). Department of Defense Budget for Fiscal Years 1990 and 1991. Washington, DC.

Department of the Air Force. (1982, March). F-15 Aircrew Training, Volume VII, Flying Training, TAC/AAC/PACAF/USAFE Manual 51-50, Volume VII.

Department of the Air Force. (1985, October). Tactical Aircrew Training, Volume I, Flying Training, TAC/AAC/PACAF/USAFE Manual 51-50, Volume I.

Directorate of Engineering and Services. (1988, April). Annual construction pricing guide for FY90 program. Washington DC: Department of the Air Force, Headquarters United States Air Force (HQ USAF/LEECD, Pentagon, Room 5D483).

Genet, R. M. (1988). The WARNET papers. (AFHRL-TP-87-63, AD A193 103). Williams Air Force Base, AZ: Air Force Human Resources Laboratory, Operations Training Division.

Graham, G. L., Menton, A.F., & Schwoerer, R. R. (1981). Training effectiveness--A total system perspective. Proceedings of the Interservice/Industry Training Systems Conference. Pp. 179-186.

Grant, R. J., & Thornley, A. (Sr. Eds.) (1987). Means square foot costs: Residential, Commercial, Industrial, Institutional (9th annual ed.) Kingston, MA: R. S. Means Company, Inc.

Houck, M. R., Thomas, G.S., & Bell, H.H. (1990, May). Requirements analysis for multiplayer air combat simulation. Unpublished paper, Air Force Human Resources Laboratory, Operations Training Division, Williams AFB, AZ.

Institute for Simulation & Training. (1990, January). Report of Industry Task Force, Navy Training - 2000.

International Institute for Strategic Studies. (1989). The Military Balance 1989-1990. Oxford, Great Britain: Nuffield Press.

Knapp, M. I., & Orlansky, J. (1983). A cost element structure for Defense Training (IDA-P-1709, AD A139 164). Institute for Defense Analyses.

Lethert, J. F. (1985). F-16 Simulators - What Have We Learned? Proceedings of the Interservice/Industry Training Systems Conference. Pp. 323-337.

Maciariello, J. A. (1975). Dynamic Benefit-Cost Analysis. Lexington, MA: D. C. Heath and Co.

McDonald, G. W., Broeder, R. F., & Cutak, R.J. (1989). Multi-ship air combat simulation. Proceedings of the Interservice/Industry Training Systems Conference. Pp. 148-158.

Olsen, S. R. (1982). The view from the other end of the microscope or I'd rather be flying. Proceedings of the Interservice/Industry Training Systems Conference. Pp. 75-78.

Orlansky, J., & Chatelier, P.R. (1983). The effectiveness and cost of simulators for training. International Conference on Simulators. Pp. 297-305.

Orlansky, J., & String, J. (1982). The cost-effectiveness of military training. Proceedings of the Interservice/Industry Training Equipment Conference. pp. 97-110.

Oxenfeldt, A. R. (1979). Cost-benefit analysis for executive decision making. New York, NY: AMACON

Pearce, D. W. (1983). Cost-benefit analysis (2nd Ed.). London, England: MacMillan Press.

Smith, V. K. (1986). A conceptual overview of the foundations of benefit-cost analysis. Bentkover et al. pp 13-34.

Steiner, H. M. (1980). Public and private investments. New York: John Wiley & Sons.

USAF in Facts and Figures (May 1990). Air Force. pp. 37-56.

U.S. General Accounting Office, (1983, January). Greater benefits to be gained from DOD flight simulators (AD A123 713). Report to C. W. Weinberger, Secretary of Defense, Washington, DC.

U.S. General Accounting Office (1987, December). Air Force Pilots: Developing and sustaining a stable, combat-ready force. (Briefing Report, GAO/NSIAD-88-49BR). Washington, DC.

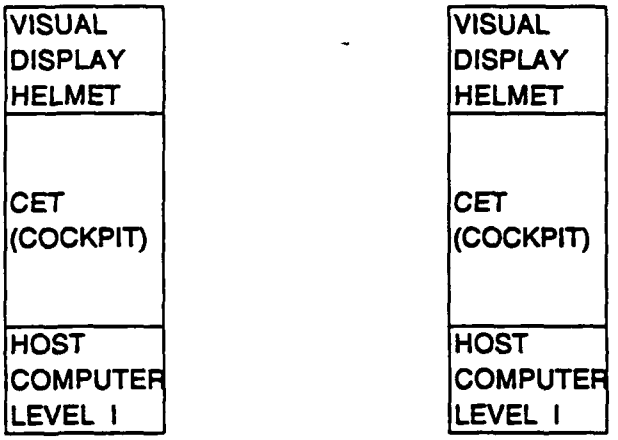
Woolsey, R. (Sr. Ed.). (1987). Means facilities cost data 1987. (2nd annual ed.). Kingston, MA: R.S. Means Company, Inc.

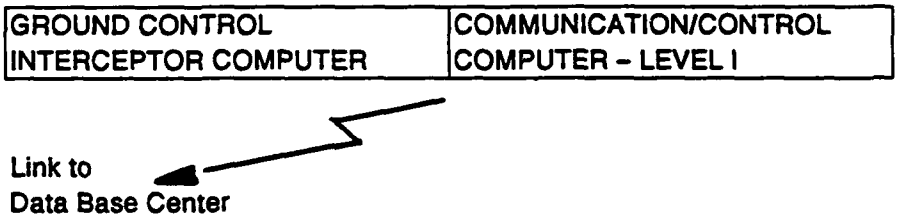
APPENDIX A

BLOCK DIAGRAMS

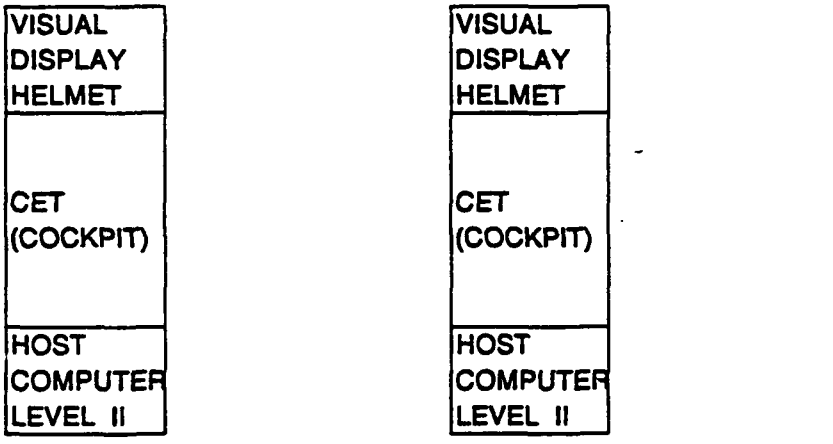
SIMULATOR COMPONENTS OF ORGANIZATIONAL ALTERNATIVES

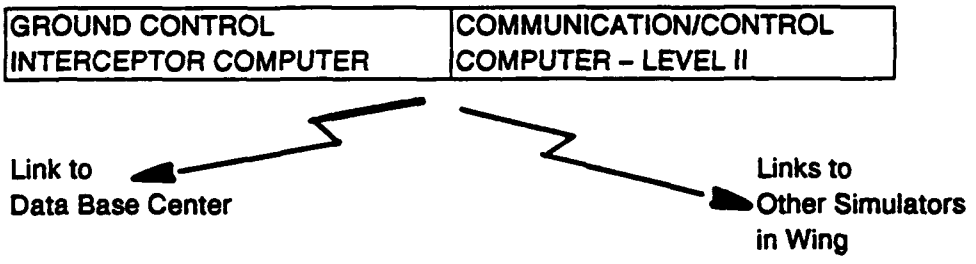
CET's (pair) in each squadron – linked
Not linked to any other simulators



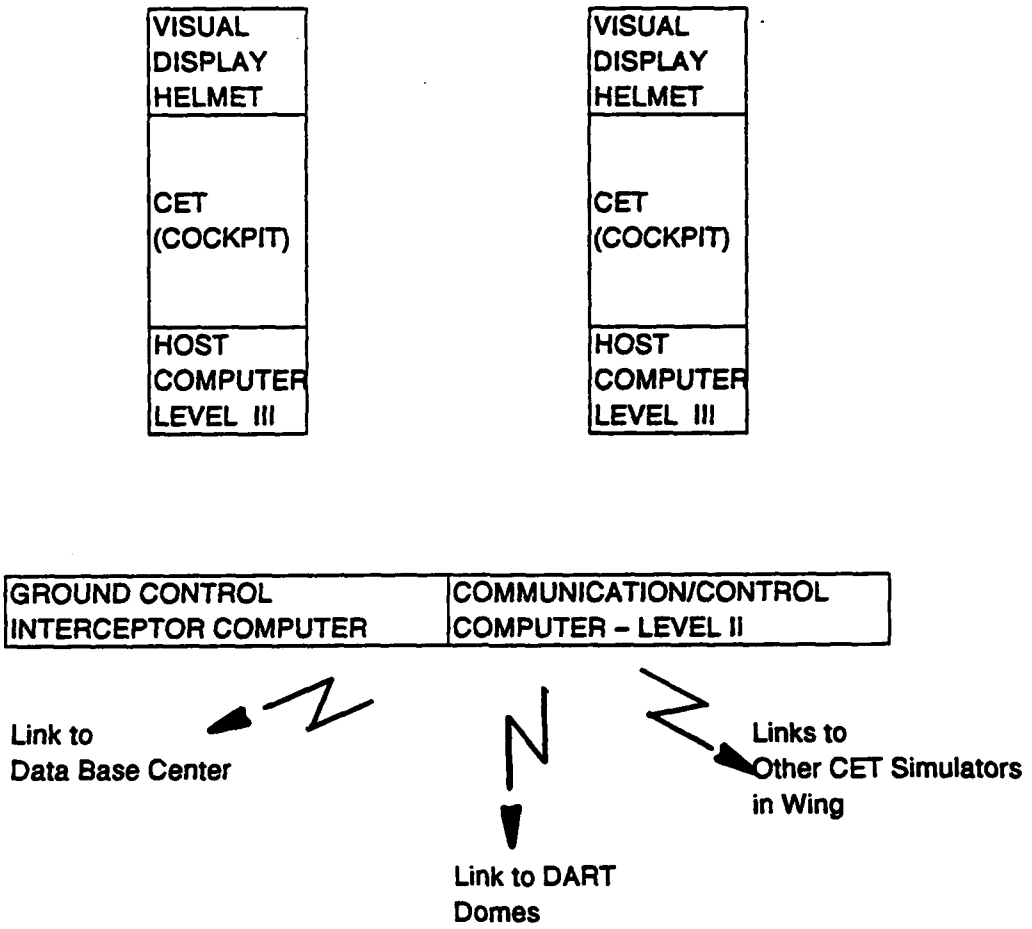


CET's (pair) in each squadron – linked
Able to link to all other simulators in wing





CET's (pair) in each squadron – linked
Able to link to all other simulators in wing
DART domes in Wing Hdqtrs. – Central Location



CET's (pair) in each squadron – linked
Able to link to all other simulators in wing
DART domes in Wing Centers

WING CENTER

HOST COMPUTER LEVEL III	VISUAL DISPLAY HELMET
IMAGE GENERATION COMPUTER	DART DOME (COCKPIT)

VISUAL DISPLAY HELMET	HOST COMPUTER LEVEL III
DART DOME (COCKPIT)	IMAGE GENERATION COMPUTER

GROUND CONTROL INTERCEPTOR COMPUTER	COMMUNICATION/CONTROL COMPUTER – LEVEL II

Link to
Data Base Center

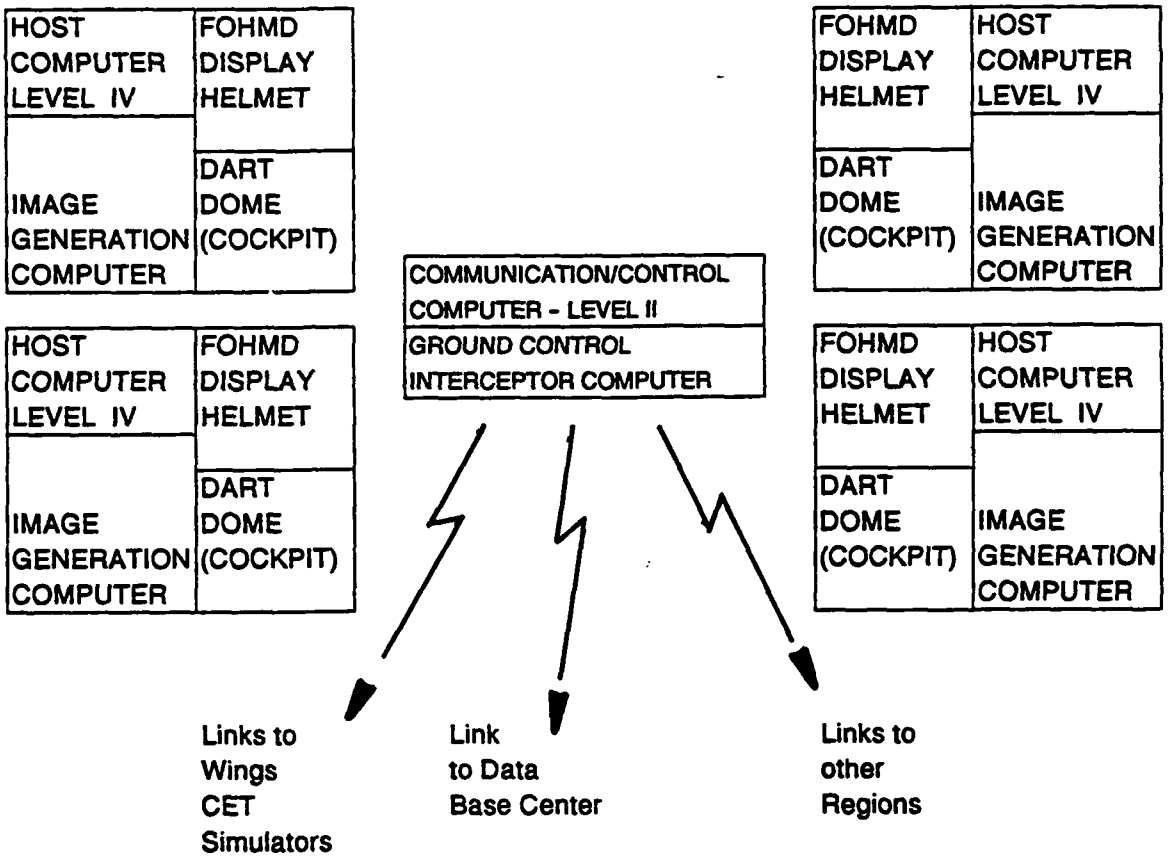
Links to
other Wings
CET
Simulators

Links to DART
Domes
Regional
Centers

Links to
Other CET Simulators
in Wing

CET's (pair) in each squadron – linked
Able to link to all other simulators in system
DART domes in Regional Centers

REGIONAL CENTER



APPENDIX B

BENEFITS MODEL

APPLIED TO INITIAL EXAMPLE

THIS REPRESENTS ORGANIZATIONAL ALTERNATIVE I
(F - 15 Air-to-Air only)

Matrix of Values for Emulation Measures ESIM(i,j)

Names of Performance Areas	Performance Areas (i)	CET Not Linked	CET Interlinked	Domes CET in squad	Regional Centers CET in squad
		Simulation Interfaces (j)			
		1	2	3	4
Air Superiority - Intercepts (Day/Night)	14	0.0150	0.0300	0.0700	0.1000
Air Superiority - ACBT	15	0.0150	0.0300	0.0700	0.1000
Air Superiority - DART	16	0.0150	0.0300	0.0700	0.1000
Air Superiority - CFT	17	0.0150	0.0300	0.0700	0.1000
Air Defense - Intercepts (Day/Night)	18	0.0150	0.0300	0.0700	0.1000
Air Defense - ACBT	19	0.0150	0.0300	0.0700	0.1000
Air Defense - DART	20	0.0150	0.0300	0.0700	0.1000

Aircraft Measures

Aircraft Sortie Time	Aircraft Repetitions
AT(i)	AR(i)
1.40	6
1.30	3
1.30	3
1.30	3
1.40	6
1.30	3
1.30	3

Simulation Repetitions SR(i,j)

Note: ST(i,j) is held = AT(i)

1	2	3	4
10	10	10	10
8	8	8	8
8	8	8	8
8	8	8	8
10	10	10	10
8	8	8	8
8	8	8	8

THIS REPRESENTS ORGANIZATIONAL ALTERNATIVE II
(F - 15 Air-to-Air only)

Matrix of Values for Emulation Measures ESIM(i,j)

Names of Performance Areas	Performance Areas (i)	CET Not Linked	CET Interlinked	Domes CET in squad	Regional Centers CET in squad
		Simulation Interfaces (j)			
		1	2	3	4
Air Superiority - Intercepts (Day/Night)	14	0.0150	0.0300	0.0700	0.1000
Air Superiority - ACBT	15	0.0150	0.0300	0.0700	0.1000
Air Superiority - DART	16	0.0150	0.0300	0.0700	0.1000
Air Superiority - CFT	17	0.0150	0.0300	0.0700	0.1000
Air Defense - Intercepts (Day/Night)	18	0.0150	0.0300	0.0700	0.1000
Air Defense - ACBT	19	0.0150	0.0300	0.0700	0.1000
Air Defense - DART	20	0.0150	0.0300	0.0700	0.1000

Aircraft Measures

Aircraft Sortie Time	Aircraft Repetitions
AT(i)	AR(i)
1.40	6
1.30	3
1.30	3
1.30	3
1.40	6
1.30	3
1.30	3

Simulation Repetitions SR(i,j)

Note: ST(i,j) is held = AT(i)

1	2	3	4
10	10	10	10
8	8	8	8
8	8	8	8
8	8	8	8
10	10	10	10
8	8	8	8
8	8	8	8

THIS REPRESENTS ORGANIZATIONAL ALTERNATIVE III
(F - 15 Air-to-Air only)

Matrix of Values for Emulation Measures ESIM(i,j)

Names of Performance Areas	Performance Areas (i)	CET Not Linked	CET Interlinked	Domes CET in squad	Regional Centers CET in squad
		Simulation Interfaces (j)			
		1	2	3	4
Air Superiority - Intercepts (Day/Night)	14	0.0150	0.0300	0.0700	0.1000
Air Superiority - ACBT	15	0.0150	0.0300	0.0700	0.1000
Air Superiority - DART	16	0.0150	0.0300	0.0700	0.1000
Air Superiority - CFT	17	0.0150	0.0300	0.0700	0.1000
Air Defense - Intercepts (Day/Night)	18	0.0150	0.0300	0.0700	0.1000
Air Defense - ACBT	19	0.0150	0.0300	0.0700	0.1000
Air Defense - DART	20	0.0150	0.0300	0.0700	0.1000

Aircraft Measures

Aircraft Sortie Time	Aircraft Repetitions
AT(i)	AR(i)
1.40	6
1.30	3
1.30	3
1.30	3
1.40	6
1.30	3
1.30	3

Simulation Repetitions SR(i,j)

Note: ST(i,j) is held = AT(i)

1	2	3	4
10	10	10	10
8	8	8	8
8	8	8	8
8	8	8	8
10	10	10	10
8	8	8	8
8	8	8	8

THIS REPRESENTS ORGANIZATIONAL ALTERNATIVE IV
(F - 15 Air-to-Air only)

Matrix of Values for Emulation Measures ESIM(i,j)

Names of Performance Areas	Performance Areas (i)	CET Not Linked	CET Interlinked	Domes CET in squad	Regional Centers CET in squad
		Simulation Interfaces (j)			
		1	2	3	4
Air Superiority - Intercepts (Day/Night)	14	0.0150	0.0300	0.0700	0.1000
Air Superiority - ACBT	15	0.0150	0.0300	0.0700	0.1000
Air Superiority - DART	16	0.0150	0.0300	0.0700	0.1000
Air Superiority - CFT	17	0.0150	0.0300	0.0700	0.1000
Air Defense - Intercepts (Day/Night)	18	0.0150	0.0300	0.0700	0.1000
Air Defense - ACBT	19	0.0150	0.0300	0.0700	0.1000
Air Defense - DART	20	0.0150	0.0300	0.0700	0.1000

Aircraft Measures

Aircraft Sortie Time	Aircraft Repetitions
AT(i)	AR(i)
1.40	6
1.30	3
1.30	3
1.30	3
1.40	6
1.30	3
1.30	3

Simulation Repetitions SR(i,j)

Note: ST(i,j) is held = AT(i)

1	2	3	4
10	10	10	10
8	8	8	8
8	8	8	8
8	8	8	8
10	10	10	10
8	8	8	8
8	8	8	8

Simulation Benefit Factors

SBEN(i,j) = ESIM(i,j)*(SR(i,j)/AR(i))

1	2	3	4
0.0250	0.0500	0.1167	0.1667
0.0400	0.0800	0.1867	0.2667
0.0400	0.0800	0.1867	0.2667
0.0400	0.0800	0.1867	0.2667
0.0250	0.0500	0.1167	0.1667
0.0400	0.0800	0.1867	0.2667
0.0400	0.0800	0.1867	0.2667

Note that NUM(i,j) is a function of scheduling AND absolute throughputs achievable by the organizational alternative being evaluated.

NUM(i,j) per year

1	2	3	4
7200	0	0	0
7200	0	0	0
7200	0	0	0
7200	0	0	0
7200	0	0	0
7200	0	0	0
7200	0	0	0

Benefit Conversion Factors

Aircraft Use	Weapons Use	Loss of Aircraft	Loss of Pilot
MACS(i)	WEAPS(i)	AIRCS(i)	PILCS(i)
$6,300.00	$2,000.00	$266.00	$116.76
$5,850.00	$2,000.00	$247.00	$108.42
$5,850.00	$2,000.00	$247.00	$108.42
$5,850.00	$2,000.00	$247.00	$108.42
$6,300.00	$2,000.00	$266.00	$116.76
$5,850.00	$2,000.00	$247.00	$108.42
$5,850.00	$2,000.00	$247.00	$108.42

OVERALL BENEFITS IMPUTED TO ORGANIZATIONAL ALTERNATIVE I

$32,596,864.00

1	2	3	4
$4,249,872.00	$0.00	$0.00	$0.00
$4,819,824.00	$0.00	$0.00	$0.00
$4,819,824.00	$0.00	$0.00	$0.00
$4,819,824.00	$0.00	$0.00	$0.00
$4,249,872.00	$0.00	$0.00	$0.00
$4,819,824.00	$0.00	$0.00	$0.00
$4,819,824.00	$0.00	$0.00	$0.00

Simulation Benefit Factors

SBEN(i,j) = ESIM(i,j)*(SR(i,j)/AR(i))

1	2	3	4
0.0250	0.0500	0.1167	0.1667
0.0400	0.0800	0.1867	0.2667
0.0400	0.0800	0.1867	0.2667
0.0400	0.0800	0.1867	0.2667
0.0250	0.0500	0.1167	0.1667
0.0400	0.0800	0.1867	0.2667
0.0400	0.0800	0.1867	0.2667

Note that NUM(i,j) is a function of scheduling AND absolute throughputs achievable by the organizational alternative being evaluated.

NUM(i,j) per year

1	2	3	4
0	7200	0	0
0	7200	0	0
0	7200	0	0
0	7200	0	0
0	7200	0	0
0	7200	0	0
0	7200	0	0

Benefit Conversion Factors

Aircraft Use	Weapons Use	Loss of Aircraft	Loss of Pilot
MACS(i)	WEAPS(i)	AIRCS(i)	PILCS(i)
$6,300.00	$2,000.00	$266.00	$116.76
$5,850.00	$2,000.00	$247.00	$108.42
$5,850.00	$2,000.00	$247.00	$108.42
$5,850.00	$2,000.00	$247.00	$108.42
$6,300.00	$2,000.00	$266.00	$116.76
$5,850.00	$2,000.00	$247.00	$108.42
$5,850.00	$2,000.00	$247.00	$108.42

OVERALL BENEFITS IMPUTED TO ORGANIZATIONAL ALTERNATIVE II

$46,890,864.00

1	2	3	4
$0.00	$5,743,872.00	$0.00	$0.00
$0.00	$7,080,624.00	$0.00	$0.00
$0.00	$7,080,624.00	$0.00	$0.00
$0.00	$7,080,624.00	$0.00	$0.00
$0.00	$5,743,872.00	$0.00	$0.00
$0.00	$7,080,624.00	$0.00	$0.00
$0.00	$7,080,624.00	$0.00	$0.00

Simulation Benefit Factors

SBEN(i,j) = ESIM(i,j)*(SR(i,j)/AR(i))

1	2	3	4
0.0250	0.0500	0.1167	0.1667
0.0400	0.0800	0.1867	0.2667
0.0400	0.0800	0.1867	0.2667
0.0400	0.0800	0.1867	0.2667
0.0250	0.0500	0.1167	0.1667
0.0400	0.0800	0.1867	0.2667
0.0400	0.0800	0.1867	0.2667

Note that NUM(i,j) is a function of scheduling AND absolute throughputs achievable by the organizational alternative being evaluated.

NUM(i,j) per year

1	2	3	4
0	7200	2400	0
0	7200	2400	0
0	7200	2400	0
0	7200	2400	0
0	7200	2400	0
0	7200	2400	0
0	7200	2400	0

Benefit Conversion Factors

Aircraft Use	Weapons Use	Loss of Aircraft	Loss of Pilot
MACS(i)	WEAPS(i)	AIRCS(i)	PILCS(i)
$6,300.00	$2,000.00	$266.00	$116.76
$5,850.00	$2,000.00	$247.00	$108.42
$5,850.00	$2,000.00	$247.00	$108.42
$5,850.00	$2,000.00	$247.00	$108.42
$6,300.00	$2,000.00	$266.00	$116.76
$5,850.00	$2,000.00	$247.00	$108.42
$5,850.00	$2,000.00	$247.00	$108.42

OVERALL BENEFITS IMPUTED TO ORGANIZATIONAL ALTERNATIVE III

$75,225,152.00

1	2	3	4
$0.00	$5,743,872.00	$3,242,624.00	$0.00
$0.00	$7,080,624.00	$4,369,808.00	$0.00
$0.00	$7,080,624.00	$4,369,808.00	$0.00
$0.00	$7,080,624.00	$4,369,808.00	$0.00
$0.00	$5,743,872.00	$3,242,624.00	$0.00
$0.00	$7,080,624.00	$4,369,808.00	$0.00
$0.00	$7,080,624.00	$4,369,808.00	$0.00

Simulation Benefit Factors

SBEN(i,j) = ESIM(i,j)*(SR(i,j)/AR(i))

1	2	3	4
0.0250	0.0500	0.1167	0.1667
0.0400	0.0800	0.1867	0.2667
0.0400	0.0800	0.1867	0.2667
0.0400	0.0800	0.1867	0.2667
0.0250	0.0500	0.1167	0.1667
0.0400	0.0800	0.1867	0.2667
0.0400	0.0800	0.1867	0.2667

Note that NUM(i,j) is a function of scheduling AND absolute throughputs achievable by the organizational alternative being evaluated.

NUM(i,j) per year

1	2	3	4
0	7200	0	2600
0	7200	0	2600
0	7200	0	2600
0	7200	0	2600
0	7200	0	2600
0	7200	0	2600
0	7200	0	2600

Benefit Conversion Factors

Aircraft Use	Weapons Use	Loss of Aircraft	Loss of Pilot
MACS(i)	WEAPS(i)	AIRCS(i)	PILCS(i)
$6,300.00	$2,000.00	$266.00	$116.76
$5,850.00	$2,000.00	$247.00	$108.42
$5,850.00	$2,000.00	$247.00	$108.42
$5,850.00	$2,000.00	$247.00	$108.42
$6,300.00	$2,000.00	$266.00	$116.76
$5,850.00	$2,000.00	$247.00	$108.42
$5,850.00	$2,000.00	$247.00	$108.42

OVERALL BENEFITS IMPUTED TO ORGANIZATIONAL ALTERNATIVE IV

$87,908,342.67

1	2	3	4
$0.00	$5,743,872.00	$0.00	$4,591,842.67
$0.00	$7,080,624.00	$0.00	$6,366,758.67
$0.00	$7,080,624.00	$0.00	$6,366,758.67
$0.00	$7,080,624.00	$0.00	$6,366,758.67
$0.00	$5,743,872.00	$0.00	$4,591,842.67
$0.00	$7,080,624.00	$0.00	$6,366,758.67
$0.00	$7,080,624.00	$0.00	$6,366,758.67

APPENDIX C

COSTS MODEL

THIS MODEL APPLIES TO ALL EXAMPLES

WCM PROJECT
REVISED 8/8/90
The cost factors are primarily drawn from Knapp and Orlansky, 1988 Modified by my reading of the rules in AF Reg. 173 -15

NOTE: P/C/D = Programs, Courses, and Devices

MODULES/ELEMENTS OF THE ALTERNATIVES TO BE EVALUATED
No entry or —— means I estimate no cost associated with this cost category for this module.

COST CATEGORIES/ELEMENTS		SQUADRON CET (Pair per squadron) Not linked to other squadrone	SQUADRON CET (Pair per squadron) Linkable to other squadrone in wing.	WING DOMES (Pair per wing). Linkable to CET's in squadrone	REGION Regional Center (Four domes linkable to any 2 pairs of simulators)	SYSTEM National Data Base Center Organizational Alternatives I & II	SYSTEM National Data Base Center Organizational Alternatives III & IV
A. RESEARCH AND DEVELOPMENT		-	-	-	-	-	-
I assume all items would be purchased		-	-	-	-	-	-
based on designs currently on hand in AL/HRA		-	-	-	-	-	-
or would be purchased from commercial firms.		-	-	-	-	-	-
There should be minimal R & D costs		-	-	-	-	-	-
except for:		-	-	-	-	-	-
		-	-	-	-	-	-
5. Prototype Manufacturing	3	$10,000.00	$10,000.00	$20,000.00	$40,000.00	$0.00	$0.00
7. P/C/D Test and Evaluation	3	$50,000.00	$50,000.00	$100,000.00	$200,000.00	$0.00	$0.00
B. INITIAL INVESTMENT		-	-	-	-	-	-
1. Production		-	-	-	-	-	-
a. Nonrecurring		-	-	-	-	-	-
(3) Industrial facilities		-	-	-	-	-	-
Buildings to house simulation devices	9	$45,448.00	$45,448.00	$271,376.00	$529,467.20	$87,157.20	$231,496.00
(4) Other	9	$10,000.00	$10,000.00	$40,000.00	$80,000.00	$10,000.00	$10,000.00
b. Recurring		-	-	-	-	-	-
Acquisition costs		-	-	-	-	-	-
Combat Engagement Trainer (CET)	9	$400,000.00	$400,000.00	$0.00	$0.00	$200,000.00	$0.00
Annual Update for CET cockpit	a	$60,000.00	$60,000.00	$0.00	$0.00	$30,000.00	$0.00
DART Dome	9	$0.00	$0.00	$1,000,000.00	$2,000,000.00	$0.00	$500,000.00
Annual Update for dome	a	$0.00	$0.00	$100,000.00	$200,000.00	$0.00	$50,000.00
Visual Display Helmet	3	$200,000.00	$200,000.00	$200,000.00	$0.00	$100,000.00	$0.00
Fiber Optic Display Helmet (FOHMD)	3	$0.00	$0.00	$0.00	$2,000,000.00	$0.00	$500,000.00
Control/Communication/Linkage Compute	3	$10,000.00	$0.00	$0.00	$0.00	$0.00	$0.00
Control/Communication/Linkage Compute	3	$0.00	$30,000.00	$30,000.00	$30,000.00	$30,000.00	$30,000.00
Host Computer - Level I	3	$80,000.00	$0.00	$0.00	$0.00	$0.00	$0.00
Host Computer - Level II	3	$0.00	$120,000.00	$0.00	$0.00	$60,000.00	$0.00
Host Computer - Level III	3	$0.00	$0.00	$200,000.00	$0.00	$0.00	$0.00
Host Computer - Level IV	3	$0.00	$0.00	$0.00	$800,000.00	$0.00	$200,000.00
Image Generating Computer Level I	3	$0.00	$0.00	$400,000.00	$0.00	$0.00	$0.00
Image Generating Computer Level II	3	$0.00	$0.00	$0.00	$1,200,000.00	$0.00	$300,000.00
Ground Control Interceptor Computer	3	$18,000.00	$18,000.00	$18,000.00	$18,000.00	$18,000.00	$18,000.00
Briefing/Debriefing Computer and Displa	3	$10,000.00	$10,000.00	$10,000.00	$10,000.00	$0.00	$0.00
c. Initial Spares and Repair Parts	3	$71,800.00	$77,800.00	$185,800.00	$805,800.00	$40,800.00	$154,800.00
5. Data		-	-	-	-	-	-
b. Technical	3	$20,000.00	$20,000.00	$20,000.00	$80,000.00	$0.00	$0.00
c. Instruction Materials	3	$20,000.00	$20,000.00	$20,000.00	$80,000.00	$0.00	$0.00
7. System/Project Management	a	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
10. Initial Training		-	-	-	-	-	-
a. Instructors (On site Operators)	9	$50,000.00	$50,000.00	$50,000.00	$50,000.00	$0.00	$0.00
b. Maintenance Personnel	9	$25,000.00	$25,000.00	$25,000.00	$25,000.00	$0.00	$0.00
12. Other	9	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
C. OPERATING AND SUPPORT		-	-	-	-	-	-
1. Direct Costs		-	-	-	-	-	-
a. Instructional Costs		-	-	-	-	-	-
(1) Pay and allowances		-	-	-	-	-	-
(a) Instructors (Simulation Operators)	a	$45,949.00	$45,949.00	$45,949.00	$81,261.00	$203,071.00	$316,289.00
(b) Supervisors, Admin, and Support Per	a	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
(c) Maintenance Personnel	a	$10,000.00	$10,000.00	$40,000.00	$80,000.00	$10,000.00	$10,000.00
(2) Other Government Personnel Costs	a	$13,987.25	$13,987.25	$21,487.25	$40,315.25	$53,287.75	$81,572.25
(3) Consumption		-	-	-	-	-	-
(c) Utilities	a	$25,000.00	$25,000.00	$37,500.00	$50,000.00	$25,000.00	$25,000.00
(d) Instructional Materials	a	$10,000.00	$10,000.00	$10,000.00	$10,000.00	$0.00	$0.00
(e) Other	a	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
(4) Replenishments, Spares	a	$25,000.00	$25,000.00	$100,000.00	$150,000.00	$25,000.00	$25,000.00
(5) Modification Material	a	$100,000.00	$100,000.00	$100,000.00	$100,000.00	$100,000.00	$100,000.00
(7) Other Purchased Services	a	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
(8) Other	a	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
b. Training Activity Costs		-	-	-	-	-	-
(1) Pay and Allowances	a	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
(2) Other Government Personnel Costs	a	$0.00	$0.00	$0.00	$349,440.00	$0.00	$0.00
(3) Other	a	$0.00	$0.00	$0.00	$249,600.00	$0.00	$0.00
e. Other Direct Costs		-	-	-	$149,760.00	$0.00	$0.00
2. Indirect Costs		-	-	-	-	-	-
a. Base Operations		-	-	-	-	-	-
b. Inventory and Supply Management		-	-	-	-	-	-
c. Military Family Housing Support		-	-	-	-	-	-
d. Command Support Costs		-	-	-	-	-	-
e. Other Indirect Costs	a	$100,000.00	$100,000.00	$100,000.00	$100,000.00	$100,000.00	$100,000.00
Total costs for 3 year capital items		$459,800.00	$555,800.00	$1,203,800.00	$5,063,800.00	$248,800.00	$1,202,800.00
Total costs for 9 year capital items		$530,448.00	$530,448.00	$1,396,376.00	$2,664,467.20	$297,157.20	$741,496.00
Total costs for annual items		$389,936.25	$389,936.25	$664,936.25	$1,410,618.25	$646,338.75	$707,861.25

VARIABLE IDENTIFICATION AND RANGE NAMES FOR VALUES USED IN THIS TABLE

Variable Identification	Name to be used for this variable. (Range Name)	Cost per Item (unless shown otherwise)	NOTES: Source of data (initials for AL/HRA personnel), assumptions made, Rats. used Number of units per module and expected life
A. RESEARCH AND DEVELOPMENT	-	-	
5. Prototype Manufacturing	PROTOMANUF	$10,000.00	1 per, 3 yr, WCM allowance est.
7. P/C/D Test and Evaluation	PCDTEST	$50,000.00	1 per, 3 yr, MT est.
B. INITIAL INVESTMENT	-	-	
1. Production	-	-	
a. Nonrecurring	-	-	
(3) Industrial facilities	-	-	
Buildings to house simulation devices	-	-	
Low Ceiling Simulator Room Costs per Sq. Ft.	LOSIMBLD	$87.40	9 yr, PER SQ. FT., Direc. of Engr. and Svc., 1988
High Ceiling Simulator Room Costs per Sq. Ft.	HISIMBLD	$129.40	9 yr, PER SQ. FT., Direc. of Engr. and Svc., 1988
Office Building Costs per Sq. Ft.	OFFBLD	$107.00	9 yr, PER SQ. FT., Direc. of Engr. and Svc., 1988
(4) Other	OTHERBLD	$10,000.00	1 per, 9 yr, WCM allowance est.
b. Recurring	-	-	
Acquisition costs	-	-	
Combat Engagement Trainer (CET)	CET	$200,000.00	9 yr, 2 per, MT and GB
Annual Update for CET cockpit	CETYRLY	$30,000.00	ann, 2 per, MT and GB
DART Dome	DART	$500,000.00	9 yr, 2 or 4 per, MT
Annual Update for dome	DARTYRLY	$50,000.00	ann, 2 or 4 per, MT
Visual Display Helmet	VDHELM	$100,000.00	3 yr, 2 or 4 per, MT and GB, WCM, IG inc.
Fiber Optic Display Helmet (FOHMD)	FOHMD	$500,000.00	3 yr, 4 per, 4 channels, MT
Control/Communication/Linkage Computer – Level I	CONCOMPI	$10,000.00	3 yr, 1 per, MT (GB?)
Control/Communication/Linkage Computer – Level II	CONCOMPII	$30,000.00	3 yr, 1 per, MT
Host Computer – Level I	HOSTCOMPI	$40,000.00	3 yr, 2 per, MT and GB
Host Computer – Level II	HOSTCOMPII	$60,000.00	3 yr, 2 per, MT and GB
Host Computer – Level III	HOSTCOMPIII	$100,000.00	3 yr, 2 per, MT and GB
Host Computer – Level IV	HOSTCOMPIV	$200,000.00	3 yr, 4 per, MT
Image Generating Computer Level I	IGCOMPI	$200,000.00	3 yr, 2 per, MT and GB
Image Generating Computer Level II	IGCOMPII	$300,000.00	3 yr, 4 per, MT and GB
Briefing/Debriefing Computer and Displays	BRFCOMP	$10,000.00	3 yr, 1 per, MT
GCI Computer	GCICOMP	$18,000.00	3 yr, 1 per, GB
c. Initial Spares and Repair Parts	INITSPRS	10.00%	3 yr, 2 or 4 per, comp. equip. allowance
5. Data	-	-	
b. Technical	TECHDATA	$20,000.00	3 yr, 1 per, DA and WCM, allowance
c. Instruction Materials	INSTDATA	$20,000.00	3 yr, 1 per, DA and WCM, allowance
7. System/Project Management	GENMGT	$0.00	ann, Available as needed for allowance
10. Initial Training	-	-	
a. Instructors (On site Operators)	TRAININST	$50,000.00	9 yr, 1 per, DA and WCM
b. Maintenance Personnel	TRAINMAIN	$25,000.00	9 yr, 1 per, DA and WCM
12. Other	OTHERINITINVEST	$0.00	3 or 9 yr, Available as needed for allowance
C. OPERATING AND SUPPORT	-	-	
1. Direct Costs	-	-	
a. Instructional Costs	-	-	
(1) Pay and allowances	-	-	
(a) Instructors (Simulation Operators)	-	-	
GS 8, STEP 5	GS8S5	$25,361.00	ann, 1 per, WCM design, GS Pay Rate
GS 6, STEP 5	GS6S5	$20,598.00	ann, 1 per, WCM design, GS Pay Rate
(b) Supervisors, Admin, and Support Personnel	-	-	
GS 3, STEP 5	GS3S5	$14,714.00	ann, 1 or 2 per, WCM design, GS Pay Rate
GS 5, STEP 5	GS5S5	$18,418.00	ann, 3 or 5 per, WCM design, GS Pay Rate
GS 10, STEP 5	GS10S5	$30,834.00	ann, 3 or 5 per, WCM design, GS Pay Rate
GS 12, STEP 5	GS12S5	$40,601.00	ann, 1 per, WCM design, Gs Pay Rate
(c) Maintenance Personnel	GENMAIN	$10,000.00	ann, 1 per, WCM allowance
(2) Other Government Personnel Costs	FRINGE	25.00%	ann, 1 per, Fringe benefits percentage
(3) Consumption	-	-	
(c) Utilities	UTILITIES	$25,000.00	ann, 1 per, WCM allowance
(d) Instructional Materials	INSTRUCCONSUMP	$10,000.00	ann, 1 per, WCM allowance
(e) Other	OTHERCONSUM	$0.00	ann, Available as needed for allowance
(4) Replenishments, Spares	SPARES	$25,000.00	ann, 1 per, WCM allowance
(5) Modification Material	MODMAT	$100,000.00	ann, 1 per, WCM allowance
(7) Other Purchased Services	OTHERPURCH	$0.00	ann, Available as needed for allowance
(8) Other	OTHERINST	$0.00	ann, Available as needed for allowance
b. Training Activity Costs	-	-	
(1) Pay and Allowances	-	-	
CAPTAINS, 10 YEARS	OFFICERS	$47,016.00	ann, Only used if required, Mil Pay Rates
(2) Other Government Personnel Costs	-	-	
TDY, OFFICERS, PER TWO WEEKS	TDYDAILY	$560.00	ann, daily rate used for Regional centers
TDY, TRAVEL	TDYTRAVEL	$800.00	ann, per trip used for Regional centers
(3) Other	OTHERPERSCST	25.00%	ann, allowance, determined from GS or Mil Rates
e. Other Direct Costs	-	-	
2. Indirect Costs	-	-	
a. Base Operations	-	-	
b. Inventory and Supply Management	-	-	
c. Military Family Housing Support	-	-	
d. Command Support Costs	-	-	
e. Other Indirect Costs	OTHERINDCSTS	$100,000.00	ann, 1 per, WCM allowance

APPENDIX D

BENEFIT-COST ANALYSIS

INITIAL EXAMPLE

COST BENEFIT ANALYSIS
Linked to files BCOSTS3 and FULL1TO4
MULTI-SHIP SIMULATION ALTERNATIVE
W. C. MOOR PROJECT
Keyed to Organizational Alternatives defined elsewhere

Prepared 7/30/90
Revised 9/28/90

BENEFITS VALUES

Organizational Alternative	Estimated Value of Benefits
Alternative I	$32,598,864.00
Alternative II	$46,890,864.00
Alternative III	$75,225,152.00
Alternative IV	$87,908,342.67

COST COMPONENT VALUES

Capital Requirement Time Period	Component Identification CET module Not Linked	Cet Module Linked	Wing Sim. Centers	Region Sim. Centers	Data Base Center I	Data Base Center II
3 Years	$489,800.00	$555,800.00	$1,203,800.00	$5,063,800.00	$248,800.00	$1,202,800.00
9 Years	$530,448.00	$530,448.00	$1,386,376.00	$2,684,467.20	$297,157.20	$741,495.00
Annual	$389,936.25	$389,936.25	$554,936.25	$1,410,616.25	$546,338.75	$707,861.25

ANNUAL EQUIVALENT VALUES FOR THE ABOVE FIGURES
Using equivalency values for the time value of money, I = 10%
3 year = 0.402114
9 year = 0.17364

COST COMPONENT VALUES

Capital Requirement Time Period	Component Identification CET module Not Linked	Cet Module Linked	Wing Sim. Centers	Region Sim. Centers	Data Base Center I	Data Base Center II
3 Years	$196,955.44	$223,494.96	$484,064.83	$2,036,224.87	$100,045.96	$483,662.72
9 Years	$92,106.99	$92,106.99	$240,730.33	$466,130.88	$51,598.38	$128,753.19
Annual	$389,936.25	$389,936.25	$554,936.25	$1,410,616.25	$546,338.75	$707,861.25
TOTAL ANNUAL EQUIVALENT VALUES PER MODULE	$678,998.68	$705,538.20	$1,279,731.41	$3,912,972.01	$697,983.09	$1,320,277.16

ANNUAL EQUIVALENT VALUES OF COSTS FOR ORGANIZATIONAL ALTERNATIVES
Assuming 18 Squadrons, 6 Wings, 4 Regional Centers and 1 Data Base Center

	Annual Costs	Annual Benefits
Alternative I 18 Squadron centers	$12,919,959.29	$32,598,864.00
Alternative II 18 Squadron centers, linked	$13,397,670.72	$46,890,864.00
Alternative III 18 Squadron centers, linked plus Wing centers	$21,698,353.27	$75,225,152.00
Alternative IV 18 Squadron centers, linked plus Regional centers	$29,671,852.83	$87,908,342.67

INCREMENTAL EQUIVALENT VALUES FOR BENEFIT COST COMPARISON

ALTERNATIVE	INCREMENTAL COSTS	INCREMENTAL BENEFITS	INCREMENTAL BENEFIT COST RATIO
I	$12,919,959.29	$32,598,864.00	2.5231
II	$477,711.43	$14,292,000.00	29.9176
III	$8,300,682.54	$28,334,288.00	3.4135
IV	$7,973,499.56	$12,683,190.67	1.5907

APPENDIX E

BENEFITS MODEL

APPLIED TO SECOND EXAMPLE

Combined spreadsheet
FULL1TO4
W. C. Moor Project
MODIFIED 9/19/91

This model uses current best estimates based on pilot interviews and literature search.
It represents as reasonable values as are currently available.
ALL DATA VALUES IN THIS PRESENTATION ARE BEST ESTIMATES

THIS REPRESENTS MASTER DATA FOR ALL ORGANIZATION ALTERNATIVES
(F - 15 Air-to-Air only)

Matrix of Values for Emulation Measures ESIM(i,j) Simulation Interfaces (j)

Names of Performance Areas	Performance Areas (i)	CET Not Linked 1	CET Interlinked 2	Domes CET in squad 3	Regional Centers CET in squad 4
Air Superiority - Intercepts (Day/Night) - EW	14A	0.0150	0.0300	0.0700	0.1000
Air Superiority - Intercepts (Day/Night) - CHAF	14B	0.0150	0.0300	0.0700	0.1000
Air Superiority - Intercepts (Day/Night) - BOTH	14C	0.0150	0.0300	0.0700	0.1000
Air Defense - Intercepts (Day/Night) - EW	18A	0.0150	0.0300	0.0700	0.1000
Air Defense - Intercepts (Day/Night) - CHAFF	18B	0.0150	0.0300	0.0700	0.1000
Air Defense - Intercepts (Day/Night) - BOTH	18C	0.0150	0.0300	0.0700	0.1000

Aircraft Measures

Aircraft Sortie Time AT(i)	Aircraft Repetitions AR(i)	
1.40		6
1.40		6
1.40		6
1.40		6
1.40		6
1.40		6

Simulation Repetitions SR(i,j) Note: ST(i,j) is held = AT(i)

1	2	3	4
10	10	10	10
10	10	10	10
10	10	10	10
10	10	10	10
10	10	10	10
10	10	10	10

THIS REPRESENTS ORGANIZATIONAL ALTERNATIVE I
(F - 15 Air-to-Air only)

Matrix of Values for Emulation Measures ESIM(i,j) Simulation Interfaces (j)

Names of Performance Areas	Performance Areas (i)	CET Not Linked 1	CET Interlinked 2	Domes CET in squad 3	Regional Centers CET in squad 4
Air Superiority - Intercepts (Day/Night) - EW	14A	0.0150	0.0300	0.0700	0.1000
Air Superiority - Intercepts (Day/Night) - CHAF	14B	0.0150	0.0300	0.0700	0.1000
Air Superiority - Intercepts (Day/Night) - BOTH	14C	0.0150	0.0300	0.0700	0.1000
Air Defense - Intercepts (Day/Night) - EW	18A	0.0150	0.0300	0.0700	0.1000
Air Defense - Intercepts (Day/Night) - CHAFF	18B	0.0150	0.0300	0.0700	0.1000
Air Defense - Intercepts (Day/Night) - BOTH	18C	0.0150	0.0300	0.0700	0.1000

Aircraft Measures

Aircraft Sortie Time AT(i)	Aircraft Repetitions AR(i)	
1.40		6
1.40		6
1.40		6
1.40		6
1.40		6
1.40		6

Simulation Repetitions SR(i,j) Note: ST(i,j) is held = AT(i)

1	2	3	4
10	10	10	10
10	10	10	10
10	10	10	10
10	10	10	10
10	10	10	10
10	10	10	10

THIS REPRESENTS ORGANIZATIONAL ALTERNATIVE II
(F - 15 Air-to- Air only)

Matrix of Values for Emulation Measures ESIM(i,j) Simulation Interfaces (j)

Names of Performance Areas	Performance Areas (i)	CET Not Linked 1	CET Interlinked 2	Domes CET in squad 3	Regional Centers CET in squad 4
Air Superiority - Intercepts (Day/Night) - EW	14A	0.0150	0.0300	0.0700	0.1000
Air Superiority - Intercepts (Day/Night) - CHAF	14B	0.0150	0.0300	0.0700	0.1000
Air Superiority - Intercepts (Day/Night) - BOTH	14C	0.0150	0.0300	0.0700	0.1000
Air Defense - Intercepts (Day/Night) - EW	18A	0.0150	0.0300	0.0700	0.1000
Air Defense - Intercepts (Day/Night) - CHAFF	18B	0.0150	0.0300	0.0700	0.1000
Air Defense - Intercepts (Day/Night) - BOTH	18C	0.0150	0.0300	0.0700	0.1000

Aircraft Measures

Aircraft Sortie Time AT(i)	Aircraft Repetitions AR(i)	
1.40		6
1.40		6
1.40		6
1.40		6
1.40		6
1.40		6

Simulation Repetitions SR(i,j) Note: ST(i,j) is held = AT(i)

1	2	3	4
10	10	10	10
10	10	10	10
10	10	10	10
10	10	10	10
10	10	10	10
10	10	10	10

THIS REPRESENTS ORGANIZATIONAL ALTERNATIVE III
(F - 15 Air-to-Air only)

Matrix of Values for Emulation Measures ESIM(i,j) Simulation Interfaces (j)

Names of Performance Areas	Performance Areas (i)	CET Not Linked 1	CET Interlinked 2	Domes CET in squad 3	Regional Centers CET in squad 4
Air Superiority - Intercepts (Day/Night) - EW	14A	0.0150	0.0300	0.0700	0.1000
Air Superiority - Intercepts (Day/Night) - CHAF	14B	0.0150	0.0300	0.0700	0.1000
Air Superiority - Intercepts (Day/Night) - BOTH	14C	0.0150	0.0300	0.0700	0.1000
Air Defense - Intercepts (Day/Night) - EW	18A	0.0150	0.0300	0.0700	0.1000
Air Defense - Intercepts (Day/Night) - CHAFF	18B	0.0150	0.0300	0.0700	0.1000
Air Defense - Intercepts (Day/Night) - BOTH	18C	0.0150	0.0300	0.0700	0.1000

Aircraft Measures

Aircraft Sortie Time AT(i)	Aircraft Repetitions AR(i)	
1.40		6
1.40		6
1.40		6
1.40		6
1.40		6
1.40		6

Simulation Repetitions SR(i,j) Note: ST(i,j) is held = AT(i)

1	2	3	4
10	10	10	10
10	10	10	10
10	10	10	10
10	10	10	10
10	10	10	10
10	10	10	10

THIS REPRESENTS ORGANIZATIONAL ALTERNATIVE IV
(F - 15 Air-to-Air only)

Matrix of Values for Emulation Measures ESIM(i,j) Simulation Interfaces (j)

Names of Performance Areas	Performance Areas (i)	CET Not Linked 1	CET Interlinked 2	Domes CET in squad 3	Regional Centers CET in squad 4
Air Superiority - Intercepts (Day/Night) - EW	14A	0.0150	0.0300	0.0700	0.1000
Air Superiority - Intercepts (Day/Night) - CHAF	14B	0.0150	0.0300	0.0700	0.1000
Air Superiority - Intercepts (Day/Night) - BOTH	14C	0.0150	0.0300	0.0700	0.1000
Air Defense - Intercepts (Day/Night) - EW	18A	0.0150	0.0300	0.0700	0.1000
Air Defense - Intercepts (Day/Night) - CHAFF	18B	0.0150	0.0300	0.0700	0.1000
Air Defense - Intercepts (Day/Night) - BOTH	18C	0.0150	0.0300	0.0700	0.1000

Aircraft Measures

Aircraft Sortie Time AT(i)	Aircraft Repetitions AR(i)	
1.40		6
1.40		6
1.40		6
1.40		6
1.40		6
1.40		6

Simulation Repetitions SR(i,j) Note: ST(i,j) is held = AT(i)

1	2	3	4
10	10	10	10
10	10	10	10
10	10	10	10
10	10	10	10
10	10	10	10
10	10	10	10

Assuming that the Organizational Alternative being evaluated will make use of some sub-set of the simulation interfaces and that only air-to-air is being trained.

Simulation Benefit Factors

SBEN(i,j) = ESIM(i,j)*(SR(i,j)/AR(i))

1	2	3	4
0.0250	0.0500	0.1167	0.1667
0.0250	0.0500	0.1167	0.1667
0.0250	0.0500	0.1167	0.1667
0.0250	0.0500	0.1167	0.1667
0.0250	0.0500	0.1167	0.1667
0.0250	0.0500	0.1167	0.1667

Note that NUM(i,j) is a function of scheduling AND absolute throughputs achievable by the organizational alternative being evaluated.

NUM(i,j) per year

1	2	3	4
8400	8400	2800	3000
8400	8400	2800	3000
8400	8400	2800	3000
8400	8400	2800	3000
8400	8400	2800	3000
8400	8400	2800	3000

Benefit Conversion Factors

Aircraft Use	Weapons Use	Loss of Aircraft	Loss of Pilot
MACS(i)	WEAPS(i)	AIRCS(i)	PILCS(i)
$6,300.00	$100,000.00	$266.00	$116.76
$6,300.00	$20,000.00	$266.00	$116.76
$6,300.00	$115,000.00	$266.00	$116.76
$6,300.00	$100,000.00	$266.00	$116.76
$6,300.00	$20,000.00	$266.00	$116.76
$6,300.00	$115,000.00	$266.00	$116.76

OVERALL BENEFITS IMPUTED TO THIS ORGANIZATIONAL ALTERNATIVE

$791,597,589.33

1	2	3	4
$25,538,184.00	$47,861,184.00	$35,796,394.67	$54,296,280.00
$8,738,184.00	$14,261,184.00	$9,663,061.33	$14,296,280.00
$28,688,184.00	$54,161,184.00	$40,696,394.67	$61,796,280.00
$25,538,184.00	$47,861,184.00	$35,796,394.67	$54,296,280.00
$8,738,184.00	$14,261,184.00	$9,663,061.33	$14,296,280.00
$28,688,184.00	$54,161,184.00	$40,696,394.67	$61,796,280.00

Simulation Benefit Factors

SBEN(i,j) = ESIM(i,j)*(SR(i,j)/AR(i))

1	2	3	4
0.0250	0.0500	0.1167	0.1667
0.0250	0.0500	0.1167	0.1667
0.0250	0.0500	0.1167	0.1667
0.0250	0.0500	0.1167	0.1667
0.0250	0.0500	0.1167	0.1667
0.0250	0.0500	0.1167	0.1667

Note that NUM(i,j) is a function of scheduling AND absolute throughputs achievable by the organizational alternative being evaluated.

NUM(i,j) per year

1	2	3	4
8400	0	0	0
8400	0	0	0
8400	0	0	0
8400	0	0	0
8400	0	0	0
8400	0	0	0

Benefit Conversion Factors

Aircraft Use	Weapons Use	Loss of Aircraft	Loss of Pilot
MACS(i)	WEAPS(i)	AIRCS(i)	PILCS(i)
$6,300.00	$100,000.00	$266.00	$116.76
$6,300.00	*$20,000.00*	*$266.00*	*$116.76*
$6,300.00	$115,000.00	$266.00	$116.76
$6,300.00	$100,000.00	$266.00	$116.76
$6,300.00	$20,000.00	$266.00	$116.76
$6,300.00	$115,000.00	$266.00	$116.76

OVERALL BENEFITS IMPUTED TO ORGANIZATIONAL ALTERNATIVE I

$125,929,104.00

1	2	3	4
$25,538,184.00	$0.00	$0.00	$0.00
$8,738,184.00	$0.00	$0.00	$0.00
$28,688,184.00	$0.00	$0.00	$0.00
$25,538,184.00	$0.00	$0.00	$0.00
$8,738,184.00	$0.00	$0.00	$0.00
$28,688,184.00	$0.00	$0.00	$0.00

Simulation Benefit Factors

SBEN(i,j) = ESIM(i,j)*(SR(i,j)/AR(i))

1	2	3	4
0.0250	0 0500	0.1167	0.1667
0.0250	0.0500	0.1167	0.1667
0.0250	0.0500	0.1167	0.1667
0.0250	0.0500	0.1167	0.1667
0.0250	0.0500	0.1167	0.1667
0.0250	0.0500	0.1167	0.1667

Note that NUM(i,j) is a function of scheduling AND absolute throughputs achievable by the organizational alternative being evaluated.

NUM(i,j) per year

1	2	3	4
0	8400	0	0
0	8400	0	0
0	8400	0	0
0	8400	0	0
0	8400	0	0
0	8400	0	0

Benefit Conversion Factors

Aircraft Use	Weapons Use	Loss of Aircraft	Loss of Pilot
MACS(i)	WEAPS(i)	AIRCS(i)	PILCS(i)
$6,300.00	$100,000.00	$266.00	$116.76
$6,300.00	$20,000.00	$266.00	$116.76
$6,300.00	$115,000.00	$266.00	$116.76
$6,300.00	$100,000.00	$266.00	$116.76
$6,300.00	$20,000.00	$266.00	$116.76
$6,300.00	$115,000.00	$266.00	$116.76

OVERALL BENEFITS IMPUTED TO ORGANIZATIONAL ALTERNATIVE II

$232,567,104.00

1	2	3	4
$0.00	$47,861,184.00	$0.00	$0.00
$0.00	$14,261,184.00	$0.00	$0.00
$0.00	$54,161,184.00	$0.00	$0.00
$0.00	$47,861,184.00	$0.00	$0.00
$0.00	$14,261,184.00	$0.00	$0.00
$0.00	$54,161,184.00	$0.00	$0.00

Simulation Benefit Factors

SBEN(i,j) = ESIM(i,j)*(SR(i,j)/AR(i))

1	2	3	4
0.0250	0.0500	0.1167	0.1667
0.0250	0.0500	0.1167	0.1667
0.0250	0.0500	0.1167	0.1667
0.0250	0.0500	0.1167	0.1667
0.0250	0.0500	0.1167	0.1667
0.0250	0.0500	0.1167	0.1667

Note that NUM(i,j) is a function of scheduling AND absolute throughputs achievable by the organizational alternative being evaluated.

NUM(i,j) per year

1	2	3	4
0	8400	2800	0
0	8400	2800	0
0	8400	2800	0
0	8400	2800	0
0	8400	2800	0
0	8400	2800	0

Benefit Conversion Factors

Aircraft Use	Weapons Use	Loss of Aircraft	Loss of Pilot
MACS(i)	WEAPS(i)	AIRCS(i)	PILCS(i)
$6,300.00	$100,000.00	$266.00	$116.76
$6,300.00	$20,000.00	$266.00	$116.76
$6,300.00	$115,000.00	$266.00	$116.76
$6,300.00	$100,000.00	$266.00	$116.76
$6,300.00	$20,000.00	$266.00	$116.76
$6,300.00	$115,000.00	$266.00	$116.76

OVERALL BENEFITS IMPUTED TO ORGANIZATIONAL ALTERNATIVE III

$404,678,805.33

1	2	3	4
$0.00	$47,861,184.00	$35,796,394.67	$0.00
$0.00	$14,261,184.00	$9,663,061.33	$0.00
$0.00	$54,161,184.00	$40,696,394.67	$0.00
$0.00	$47,861,184.00	$35,796,394.67	$0.00
$0.00	$14,261,184.00	$9,663,061.33	$0.00
$0.00	$54,161,184.00	$40,696,394.67	$0.00

Simulation Benefit Factors

SBEN(i,j) = ESIM(i,j)*(SR(i,j)/AR(i))

1	2	3	4
0.0250	0.0500	0.1167	0.1667
0.0250	0.0500	0.1167	0.1667
0.0250	0.0500	0.1167	0.1667
0.0250	0.0500	0.1167	0.1667
0.0250	0.0500	0.1167	0.1667
0.0250	0.0500	0.1167	0.1667

Note that NUM(i,j) is a function of scheduling AND absolute throughputs achievable by the organizational alternative being evaluated.

NUM(i,j) per year

1	2	3	4
0	8400	0	3000
0	8400	0	3000
0	8400	0	3000
0	8400	0	3000
0	8400	0	3000
0	8400	0	3000

Benefit Conversion Factors

Aircraft Use	Weapons Use	Loss of Aircraft	Loss of Pilot
MACS(i)	WEAPS(i)	AIRCS(i)	PILCS(i)
$6,300.00	$100,000.00	$266.00	$116.76
$6,300.00	$20,000.00	$266.00	$116.76
$6,300.00	$115,000.00	$266.00	$116.76
$6,300.00	$100,000.00	$266.00	$116.76
$6,300.00	$20,000.00	$266.00	$116.76
$6,300.00	$115,000.00	$266.00	$116.76

OVERALL BENEFITS IMPUTED TO ORGANIZATIONAL ALTERNATIVE IV

$493,356,784.00

1	2	3	4
$0.00	$47,861,184.00	$0.00	$54,296,280.00
$0.00	$14,261,184.00	$0.00	$14,296,280.00
$0.00	$54,161,184.00	$0.00	$61,796,280.00
$0.00	$47,861,184.00	$0.00	$54,296,280.00
$0.00	$14,261,184.00	$0.00	$14,296,280.00
$0.00	$54,161,184.00	$0.00	$61,796,280.00

APPENDIX F

BENEFIT-COST ANALYSIS

APPLIED TO SECOND EXAMPLE

COST BENEFIT ANALYSIS — Prepared 7/30/90
Linked to files BCOSTS3 and TBENEF — Revised 9/28/90
MULTI-SHIP SIMULATION ALTERNATIVE
W. C. MOOR PROJECT
Keyed to Organizational Alternatives defined elsewhere

BENEFITS VALUES

Organizational Alternative	Estimated Value of Benefits
Alternative I	$125,929,104.00
Alternative II	$232,567,104.00
Alternative III	$404,878,805.33
Alternative IV	$493,356,784.00

COST COMPONENT VALUES

Capital Requirement		Component Identification				
Time Period	CET module Not Linked	Cet Module Linked	Wing Sim. Centers	Region Sim. Centers	Data Base Center I	Data Base Center II
3 Years	$489,800.00	$555,800.00	$1,203,800.00	$5,063,800.00	$248,800.00	$1,202,800.00
9 Years	$530,448.00	$530,448.00	$1,386,376.00	$2,684,467.20	$297,157.20	$741,495.00
Annual	$389,936.25	$389,936.25	$554,936.25	$1,410,616.25	$546,338.75	$707,861.25

ANNUAL EQUIVALENT VALUES FOR THE ABOVE FIGURES
Using equivalency values for the time value of money, i = 10%
3 year = 0.402114
9 year = 0.17364

COST COMPONENT VALUES

Capital Requirement		Component Identification				
Time Period	CET module Not Linked	Cet Module Linked	Wing Sim. Centers	Region Sim. Centers	Data Base Center I	Data Base Center II
3 Years	$196,955.44	$223,494.96	$484,064.83	$2,036,224.87	$100,045.96	$483,662.72
9 Years	$92,106.99	$92,106.99	$240,730.33	$466,130.88	$51,598.38	$128,753.19
Annual	$389,936.25	$389,936.25	$554,936.25	$1,410,616.25	$546,338.75	$707,861.25
TOTAL ANNUAL EQUIVALENT VALUES PER MODULE	$678,998.68	$705,538.20	$1,279,731.41	$3,912,972.01	$697,983.09	$1,320,277.16

ANNUAL EQUIVALENT VALUES OF COSTS FOR ORGANIZATIONAL ALTERNATIVES
Assuming 18 Squadrons, 6 Wings, 4 Regional Centers and 1 Data Base Center

	Annual Costs	Annual Benefits
Alternative I 18 Squadron centers	$12,919,959.29	$125,929,104.00
Alternative II 18 Squadron centers, linked	$13,397,670.72	$232,567,104.00
Alternative III 18 Squadron centers, linked plus Wing centers	$21,698,353.27	$404,878,805.33
Alternative IV 18 Squadron centers, linked plus Regional centers	$29,671,852.83	$493,356,784.00

INCREMENTAL EQUIVALENT VALUES FOR BENEFIT COST COMPARISON

ALTERNATIVE	INCREMENTAL COSTS	INCREMENTAL BENEFITS	INCREMENTAL BENEFIT COST RATIO
I	$12,919,959.29	$125,929,104.00	9.7469
II	$477,711.43	$106,638,000.00	223.2268
III	$8,300,682.54	$172,311,701.33	20.7587
IV	$7,973,499.56	$88,477,978.67	11.0965